State of Connecticut.

PUBLIC DOCUMENT No. 34.

SIXTEENTH ANNUAL REPORT

OF THE

STORRS

AGRICULTURAL EXPERIMENT STATION,

STORRS, CONN.

FOR THE YEAR ENDING JUNE 30, 1904.

PRINTED BY ORDER OF THE LEGISLATURE

MIDDLETOWN, CONN.
PELTON & KING, PRINTERS AND BOOKBINDERS.
1904

BOARD OF CONTROL.

THE BOARD OF TRUSTEES

OF THE

CONNECTICUT AGRICULTURAL COLLEGE.

TREASURER.

E. O. SMITH, Storrs.

STATION COUNCIL.

R. W. STIMSON,	*President of the Connecticut Agricultural College.*
G. A. HOPSON,	*Appointed by Board of Trustees.*
L. A. CLINTON,	*Director.*
A. G. GULLEY,	*Appointed by Station Staff.*
C. L. BEACH,	*Appointed by Station Staff.*

STATION STAFF.

L. A. CLINTON,	*Director.*
H. W. CONN,	*Supervisor Dairy Bacteriology.*
W. O. ATWATER,	*Supervisor Nutrition Investigations.*
A. G. GULLEY,	*Horticulturist.*
C. L. BEACH,	*Dairy Husbandman.*
B. B. TURNER,	*Chemist.*
W. A. STOCKING, JR.,	*Assistant Bacteriologist.*
F. H. STONEBURN,	*Poultryman.*
E. R. BENNETT,	*Assistant Horticulturist.*
H. L. GARRIGUS,	*Assistant Field Experimenter.*
W. M. ESTEN,	*Laboratory Assistant.*
*B. F. KOONS,	*Consulting Entomologist.*
E. H. LEHNERT,	*Consulting Veterinarian.*
E. A. WHITE,	*Consulting Botanist.*
CHARLES THOM,	*Cheese Expert, Mycologist.*
A. W. BOSWORTH,	*Cheese Expert, Chemist.*

*Died December 17, 1903.

CONTENTS.

Publications of the Station

AVAILABLE FOR FREE DISTRIBUTION.

THE STORRS AGRICULTURAL EXPERIMENT STATION is located in Mansfield Township, Tolland County, Connecticut, and is under the control of the Board of Trustees of the Connecticut Agricultural College. The freight and express station is Eagleville, Conn., on the Central Vermont Railroad. The telegraph address is Willimantic, with which city the Station is connected by telephone. Long distance telephone connection brings all points of the State into direct communication with the Station.

The following publications of the Station are available for distribution and will be sent free on request as long as the supply lasts.

All correspondence should be addressed to

STORRS AGRICULTURAL EXPERIMENT STATION,
STORRS, CONNECTICUT.

BULLETINS.

No. 5. Atmospheric Nitrogen as Plant Food.
No. 6. Grass and Forage Garden. Grasses and Legumes.
No. 7. Chemistry and Economy of Food.
No. 9. Soiling and Soiling Crops. Feeding Experiments with Soiling Crops.
No. 12. The Ripening of Cream by Artificial Bacteria Cultures.
No. 14. The Elm Leaf Beetle.
No. 20. A Study of Dairy Cows.
No. 21. The Ripening of Cream.
No. 22. The Soy Bean as a Forage and Seed Crop.
No. 23. The Relation of Bovine Tuberculosis to that of Man and its Significance in the Dairy Herd.
No. 24. The History of a Tuberculous Herd of Cows.

No. 25. The Covered Pail a Factor in Sanitary Milk Production.

No. 26. The Relation of Temperature to the Keeping Property of Milk.

No. 27. Poultry as Food.

No. 28. Dairy Observations.

No. 29. Records of a Dairy Herd for Five Years.

No. 30. Spraying Notes for 1903.

No. 31. Food Value of a Pound of Milk Solids.

No. 32. Protecting Cows from Flies.

No. 33. A Successful Brooder House.

No. 34. Discussion of the Amount of Protein Required in the Ration for Dairy Cows.

REPORTS.

The Reports of the Storrs Agricultural Experiment Station for 1889, '90, '91, 94, '95, '96, Part II. '98, '99, 1900, 1901, 1902–3, 1904, are available for free distribution.

Address all requests to the Director of Storrs Agricultural Experiment Station, Storrs, Conn.

Report of the Executive Committee.

To His Excellency Abiram Chamberlain,

Governor of Connecticut.

In accordance with the resolution of the General Assembly concerning the congressional appropriations to the Agricultural Experiment Stations, and an act of the General Assembly approved March 19, 1895, relating to the publications of the Reports of the Storrs Agricultural Experiment Station, we have the honor to present herewith the Sixteenth Annual Report of that Station; namely, that for the year ending June 30, 1904.

The accompanying report of the Treasurer gives the details of receipts and expenditures. We refer you to the report of the Director and his associates for a statement of the work accomplished during the past year.

Respectfully submitted,

GEORGE A. HOPSON,
B. C. PATTERSON,
GEORGE S. PALMER,
Executive Committee.

Report of the Treasurer

For the Fiscal Year Ending June 30th, 1904.

The following summary of receipts and expenditures, made out in accordance with the form recommended by the United States Department of Agriculture, includes, first, the Government appropriation of $7,500, and, secondly, the annual appropriation of $1,800 made by the State of Connecticut, together with various supplemental receipts. These accounts have been duly audited according to law, as is shown by the Auditors' certificates, copies of which are appended.

GOVERNMENT APPROPRIATION—RECEIPTS AND EXPENDITURES.

RECEIPTS.	
United States Treasury,	$7,500 00
EXPENDITURES.	
Salaries,	$3,160 13
Labor,	1,185 32
Publications,	51 81
Postage and stationery,	252 98
Freight and express,	67 35
Heat, light, water, and power,	368 13
Chemical supplies,	403 89
Seeds, plants, and sundry supplies,	300 19
Feeding stuffs,	132 73
Library,	5 95
Tools, implements, and machinery,	180 73
Furniture and fixtures,	85 25
Scientific apparatus,	482 74
Live stock,	434 92
Traveling expenses,	304 63
Contingent expenses,	60 00
Buildings and repairs,	23 25
	$7,500 00

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1904, that we have found the same well kept and classified as above, and that the receipts for the year from the Treasurer of the United States are shown to have been $7,500 and the corresponding disbursements $7,500, for all of which proper vouchers are on file and have been examined by us and found correct, thus leaving no balance.

And we further certify that the expenditures have been solely for the purposes set forth in the act of Congress, approved March 2, 1887.

(Signed,) Geo. A. Hopson, }
Chas. A. Capen, } *Auditors.*

Storrs, Conn., July 15, 1904.

STATE APPROPRIATION AND SUPPLEMENTAL RECEIPTS—RECEIPTS AND EXPENDITURES.

RECEIPTS.

State of Connecticut,	$1,800 00
Miscellaneous receipts,	15 71
	$1,815 71

EXPENDITURES.

Salaries,	$1,076 03
Labor,	100 25
Publications,	13 56
Postage and stationery,	108 68
Freight and express,	4 76
Heat, light, water and power,	23 13
Chemical supplies,	108 61
Seeds, plants, and sundry supplies,	255 20
Furniture and fixtures,	63 67
Scientific apparatus,	51 99
Traveling expenses,	9 83
	$1,815 71

AUDITORS' CERTIFICATE.

We, the undersigned, duly appointed Auditors of the Corporation, do hereby certify that we have examined the books and accounts of the Storrs Agricultural Experiment Station for the fiscal year ending June 30, 1904, and that we have found the same well kept and classified as above, and that the receipts for the year from the State of Connecticut are shown to have been $1,800 and the receipts from miscellaneous sources are shown to have been $15.71, making the total receipts from the State and miscellaneous sources $1,815.71 and the corresponding disbursements $1,815.71, for all of which proper vouchers are on file and have been by us examined and found to be correct, thus leaving no balance.

(Signed,) GEO. A. HOPSON, CHAS. A. CAPEN, } *Auditors.*

STORRS, CONN., July 15, 1904.

E. O. SMITH, *Treasurer.*

Report of the Director.

The Storrs Agricultural Experiment Station is organized under an act of Congress, approved March 2, 1887, and it is established "To aid in acquiring and diffusing among the people of the United States useful and practical information on subjects connected with agriculture and to promote scientific investigation and to experiment respecting the principles and application of agricultural science."

The Experiment Station is maintained by a federal appropriation of $7,500 per year and by a state appropriation of $1,800 per year. Only one-half of the federal appropriation for experiment station work in Connecticut is received by the Storrs Experiment Station. In addition to the direct state appropriation of $1,800, the printing of the annual report and the bulletins of the Station is paid for by the state.

In carrying on the work of investigation the Station has been fortunate in being able to coöperate in certain lines of work with the United States Department of Agriculture, and as a result of this coöperation experiments have been undertaken and results have been secured and the work of the Station has been greatly enhanced. The Station is also indebted to the Connecticut Agricultural College for valuable assistance. Only through the coöperation of Station and College have we been able to carry on much of the work which has been in progress. The College has freely permitted men in its employment to conduct experiments and to give to the Station the benefit of their work. To President R. W. Stimson and the Board of Trustees of the College and Station credit should be given not only for sympathy with our work, but for actual assistance rendered personally and through the College employees.

CHANGES IN THE STAFF.

During the past year several changes have occurred in the staff of the Experiment Station. Dr. B. F. Koons, consulting entomologist, died Dec. 17, 1903. While Dr. Koons had not

been engaged in active experimental work for the Station, yet as a consulting member of our staff he was able to give advice which was of value; and in losing his services in connection with the Station we have lost not only a friend to agricultural progress, but a wise counsellor as well.

Through coöperation with the Dairy Division of the Bureau of Animal Industry of the United States Department of Agriculture we have secured the services of three additional members of our staff, who are engaged in cheese investigation—Dr. Charles Thom as mycologist, Mr. A. W. Bosworth as chemist, and a practical cheese expert who is not yet appointed.

STATION FINANCES.

Owing to the limited amount of money which is available for Station use it is necessary to limit the work to a few lines and to do this work thoroughly, rather than to attempt a large amount of work in various lines. In the equipment of laboratories we have endeavored to make them thoroughly efficient and adapted to our work.

The state appropriation of $1,800 is given for a specific purpose; namely, for investigations in food nutrition and in dairy bacteriology. If additional state aid could be secured, the Station would be enabled to broaden its work and to be of greater service to the agricultural interests than it is at the present time.

DAIRY BACTERIOLOGY.

Along the lines of dairy bacteriology the work of the Storrs Station is second to none. The practical value of this line of work is coming to be appreciated more as greater attention is given to milk as a food. Milk, if properly handled, is one of the most wholesome and one of the most nutritious of foods; and if improperly handled, it may become one of the most dangerous and insidious enemies of the human race. We believe there is no more important work in which our Station can be engaged than to investigate conditions under which wholesome milk can be produced and the means by which this milk may be preserved and delivered to the consumer in a wholesome condition. The larger part of the milk produced in Connecticut is sold as whole milk, and the dairy industry of the state is one of its

most important sources of wealth. Every citizen of the state should be interested in questions which relate to the production of pure, wholesome milk.

DAIRY HUSBANDRY.

The care and management of the dairy herd, the selection of the dairy cow, and special problems which relate to feeding have been investigated during the past year. For several years a careful record has been kept of the cost and keeping of various cows in the College herd and of the returns from each cow. These records have been published during the past year, and they show that in 1899 the College herd netted a loss of $1.23 on each animal, and that in 1903, by care in selection and by disposing of the unprofitable animals, the net profit for each animal in the herd was $21.64. The average cost of the animals which were added to the herd in this time was $42.50. These results show what can be done by intelligent management of the dairy herd. Several papers are published in this report which give, in part, results of work accomplished by the dairy division.

HORTICULTURAL INVESTIGATIONS.

The work along horticultural lines has been in part the determination of how various insect and fungous enemies can be most efficiently conquered and the testing of varieties of fruits and vegetables. The horticultural division of the Experiment Station is one of the divisions recently established, and from the interest taken in this work by the fruit growers of the state it is evident that the work is appreciated and that it should receive larger financial support than we are able at the present time to give it.

POULTRY INVESTIGATION.

Valuable work has been done during the past year in securing data with reference to the raising of squabs, the feeding of ducks, and profitable management of poultry for egg production. The Station now possesses a select loft of pigeons, and we hope in the near future to give some definite information with reference to the profits of squab raising to those who are thinking of engaging in this business.

ALFALFA INVESTIGATIONS.

For the past two years we have been experimenting with alfalfa. In coöperation with the Division of Agrostology of the United States Department of Agriculture, alfalfa seed has been distributed in small lots to many farmers in the state. Soil for inoculating purposes has been secured from central New York, and has been sent to many who received alfalfa seed.

While definite conclusions cannot yet be drawn, still as a result of our experiments up to the present time we are compelled to say that alfalfa as a crop is not generally adapted to Connecticut conditions. We believe, however, that in time information will be secured as to the special needs of the crop in this state; but until this information is secured, farmers of the state should sow alfalfa only in an experimental way. They should not be disappointed in case of failure, and the probability is that by persistent seeding of the same ground to alfalfa year after year and by fertilizing liberally with stable manure, a crop of alfalfa will finally be secured. The necessary bacteria for alfalfa growth seem to establish themselves gradually where the same ground is seeded to alfalfa year after year.

SPRAYING POTATOES.

In the fall of 1903, from 25 to 50 per cent. of the potato crop of Connecticut was lost by rot resulting from potato blight. In many cases where potatoes had been sprayed with Bordeaux mixture they did not successfully resist blight.

As a result of investigations covering a period of eight years we are led to believe that if potato spraying is to be effective as a preventive of blight, it must be done more thoroughly than it can be done by the automatic spray carts of the present time. Either the spraying must be done by hand, the nozzles being held so that all parts of the potato vines will be thoroughly covered with the spray, or the spraying machinery must be greatly improved.

CHEESE INVESTIGATION.

One important line of work which has been actively entered upon during the past year relates to the manufacture of soft cheese. At the present time nearly all of the cheese used in

this country of the type of the Roquefort and Camembert is imported. Could this cheese be manufactured by our dairymen, it would not only supply an ever increasing demand, but it would establish a new industry in New England and furnish a profitable market for any surplus milk. So important is this line of work, that we have secured the coöperation of the Dairy Division of the Bureau of Animal Industry of the United States Department of Agriculture. We acknowledge here valuable aid received from Major Alvord, Chief of the Dairy Division, and from Dr. Salmon, Chief of the Bureau of Animal Industry, and from Secretary Wilson, through whose active interest in this work we have been able to continue our experiments.

NUTRITION INVESTIGATIONS.

The Station retains its relations with Dr. W. O. Atwater, and the nutrition investigations which have formed a large and important part of the Station work since its organization are still conducted at Middletown, in the laboratories of Wesleyan University. While the amount of money which the Station can devote to this work is not as great as we could wish, yet one-half of the state appropriation of $1,800 is given to Dr. Atwater to aid in his investigations. The results secured are far in excess of what could be secured by the Station without coöperation. While the results of this nutrition investigation may not appeal to the Connecticut farmer as being of special value to him, yet these investigations are most far reaching in their effects, and may result in economies in the use of food which will be of direct and specific importance in the most humble home.

PUBLICATIONS.

The printing of the bulletins and reports of the Station is provided for by the state of Connecticut. Acknowledgment is due Comptroller W. E. Seeley for permission to increase somewhat the size of our editions. The demand for our bulletins has become so great that we have been compelled in some cases to publish a second edition. We are now enabled to increase our editions from eight thousand to ten thousand copies; but at the present rate of increase in the demand for our bulletins the time is not far distant when even larger editions will be necessary.

The members of the Station Staff have attended many farmers' meetings in the state during the past year, and have given addresses on different subjects related to agriculture. While this work is not experimental in its character, yet it is one way of disseminating information, and we feel that the more intimate the relation between the Experiment Station workers and the farmers of the state, the better work we shall be able to do for the agricultural interests of the state. We hope that in the near future we shall be able to enlarge our work, either through additional state aid or an increase in the federal appropriation, or both.

L. A. CLINTON.

Report of the Supervising Bacteriologist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—I beg to submit the following report of the work done under my direction in the Station during the past year.

The work in dairy bacteriology has consisted of several independent pieces of investigation.

1. The investigation upon the relation of temperature to the types of bacteria that grow in milk, of which a partial report was given in the last annual bulletin, has been continued and extended. A long series of experiments upon the effect upon the same lot of milk of preserving it at various temperatures—1°, 10°, 20°, and 30°—has been carried on, and a report of these experiments will be found in the following pages. The general result has been to show that variations in temperature not only greatly affect the rapidity in growth of bacteria in milk, but also affect the species which develop. It has been found that the temperature favoring the most useful dairy species is 20°C. At higher temperatures species grow which are unsatisfactory both for butter making and cheese making; and at lower temperatures, though the development is much slower, the bacteria do develop in time, and there is much greater probability that the species which eventually develop will injure or ruin the milk, rendering it unwholesome as a food.

2. Experiments which were begun a year ago, upon the manufacture of soft cheeses, have been continued and greatly extended. In this work the Agricultural Department has associated with the Experiment Station two investigators. Dr. Charles Thom, as mycologist, is undertaking the study of the fungi connected with the ripening of soft cheeses, and will report the outline of the work he has undertaken. Mr. A. W. Bosworth, the chemist, is undertaking the solution of some of the chemical problems for the ripening of these cheeses, and a

report of his work will appear separately. The bacteriological work upon the same problem is being performed by Mr. Stocking and Mr. Esten, and consists in the study of all species of bacteria found in imported cheeses, together with their effect upon milk and cheese ripening. The experiments in question are as yet only in the introductory stage, and no report can be made upon them.

3. Work upon barn conditions as affecting the number of bacteria in milk has been undertaken by Mr. Stocking. The work is not yet ready for publication.

4. Two series of studies upon the so-called germicidal property of milk have been carried on, one by Mr. Stocking at Storrs and the other by Mr. H. C. Ward, who has done his work in Middletown. The results of this work will appear in the present annual report. The general conclusion has been that there is no propriety in the use of the term "germicidal property," since the phenomena in question are due to the inability of some species to live in a milk medium, while other species multiply uniformly from the start.

5. A most extensive piece of work undertaken has been the preparation of a more satisfactory classification of the species of bacteria found in dairy products. This work, which has been incidentally carried on for the last six years, is now being pushed with greater energy than at any time before. A plan of description, classification, and indexing of species has been devised, which very greatly facilitates the study in question; and it is now the intention to make bacteriological studies of all species of dairy organisms which are obtainable, both from this vicinity and from other sources. This work is one of considerable magnitude, and while great progress has been made in it, it is still far from complete. No report upon the same can be given at the present time, but it is hoped that during the coming year the study may be so extended as to make it possible to give, in the next annual report, a tolerably complete account of the dairy bacteria known at the present time.

Respectfully submitted,

H. W. CONN.

Report of the Dairy Husbandman.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—I herewith submit a brief outline of the work of the Dairy Department for the year ending June 30, 1904.

1. The effect upon milk flow of the application of "fly repellants" to dairy cows has been investigated for two summers. The results are given in this report.

2. During the past year eight pair of young, growing animals have been fed milk "poor" in fat in comparison with milk "rich" in fat. A comparison was made of the gain in live weight resulting from a pound of solids in each milk. Less gain in weight resulted in each case from the rich milk, when equal quantities of solids were fed. This result is attributed to the larger fat globules, affecting the digestibility of the milk rich in fat.

3. The effect of silage in the ration of dairy cows upon the acidity of the milk is reported from a few trials.

4. A confirmed seven day butter fat test of the Jersey cow, "Butterfly Maid," is given in the report.

In coöperation with the Ayrshire Breeders' Association, samples of milk from one herd in Connecticut are being tested monthly. The Station is willing to take up this work with other cattle associations or with individual farmers.

5. Several trials, showing the result on milk and butter fat yield of milking three times a day at uneven periods, are given and commented upon.

Respectfully submitted,

CHARLES L. BEACH.

Report of the Horticulturist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—No part of the salary of the Horticulturist being paid from the Station funds, it is not expected that much of his time will be directly devoted to experiment work. The experiments on vegetables are almost wholly in charge of the Assistant Horticulturist, and he will report upon them. The writer is carrying out a series of experiments started some years since to determine the effects of stocks upon different varieties, and variety tests on apples as to quality and crop. In all of these some results are expected when the crop is harvested, as many of the trial trees are bearing; but nothing definite can be reported at this date. The much discussed question of how the rot on plum may be controlled by spraying is being given special attention in the trial orchard of the College, where many varieties are in full bearing. Some attention is being devoted to results of spraying upon the foliage of other stone fruits.

In coöperation with the Department of Agriculture at Washington, variety tests of sweet corn and beans are in progress. The work is largely the comparison of strains of the same variety and the growing of similarly named kinds from different seeds to note whether the varieties are not identical. Tests of quality will follow later, but here as before results will not be known until the close of the season.

Much time each winter is devoted to institute work over the state. All questions in connection with fruit growing excite much interest. The new ones developed by the effects of the extreme winters just passed promise to keep the student in horticulture busy; and at no place in New England is there a better chance of settling some of them, at least, than in the orchards growing upon the College grounds.

Respectfully submitted,

A. G. GULLEY.

Report of the Assistant Horticulturist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The importance of the vegetable growing industry of this state has made it seem advisable to give considerable attention to the methods of culture and the treatment of diseases affecting garden products.

The work of last year in spraying melons and cucumbers with Bordeaux mixture for melon blight is being repeated here at the Station with observations on similar work done in various parts of the state.

Spraying for fungi on tomatoes, apples, and potatoes is being carried on here.

About one-tenth of an acre has been covered with cloth, under which tomatoes, lettuce, cabbage, cauliflower, strawberries, cucumbers, muskmelons, and sweet corn are being grown. Duplicate plots of these vegetables are growing outside for comparison.

Cultural experiments with cabbage, tomato, and sweet corn are in progress.

Respectfully submitted,

E. R. BENNETT.

Report of the Poultryman.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—During the year just closed the work of the Poultry Division has been continued along the lines indicated in the last report. Particular attention has been given the problem of producing squabs for market, and very satisfactory results have been secured. Additional breeding birds of varieties suitable for squab production have been added to the Station lofts, and these are being bred in their purity as well as crossed in order to ascertain which breed or cross will produce the largest number of high grade squabs. The correspondence of the division indicates a very general interest in this special line of work, and its continuance is recommended.

The work with ducks continues. At the present time the effects of inbreeding and confinement of breeding stock are being investigated with reference to fertility of eggs and vigor of young. Feeding experiments begun last year are being continued.

Respectfully submitted,

F. H. STONEBURN.

Report of the Consulting Veterinarian.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The official duties of this department of the Station staff consist mostly of answering letters of inquiry with regard to animals suffering from various diseases, and occasional visits to farms when the difficulty seems to warrant investigation and the expense. During the past year one visit was made to the Church family of Shakers, Shaker Station, where for some time they had been losing nearly all their young calves. Investigation showed that the calves succumbed to a peculiar infectious diarrhea known as "white scours." The outbreak was apparently checked by strenuous disinfection of stables, improving ventilation, and cleanliness, as well as by observing certain methods in the care of the new-born calf, the most important being the early disinfecting and ligating of the umbilical cord. Attention was also called to the necessity of cleanliness of all feeding vessels and a proper regard for the temperature of the milk and the time of feeding.

A visit was paid recently to the farm of Mr. Charles Jarvis of Berlin, Conn., to investigate the cause of persistent and extensive abortion in his dairy herd. No doubt could be entertained after looking over the stable and herd and conversing with the farmer that the trouble was "contagious abortion." Mr. Jarvis willingly agreed to methods of stable disinfection, etc., that were suggested. The stables have all been washed and scraped and then washed with a strong carbolic solution and finally given a coat of strong lime wash containing five per cent. carbolic acid. All flooring and other parts of the stable that needed repairing have been replaced with new material.

Directions have been given for disinfection and for care of the breeding stock, which, if carried out, will in all probability remedy the trouble.

No experimental work has been carried on during the year under the direct auspices of the Station, but further experience has been gained of the effect of oxygen in cases of milk fever, which is reported elsewhere in this volume.

Respectfully submitted,

E. H. LEHNERT.

Report of the Chemist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The work of the Chemical Department of the Experiment Station for the year 1903–4 has been chiefly of a preliminary character. A commencement has been made with an investigation of the starch content of potatoes and its influence on quality; and an apparatus is being constructed for investigating the fertilizing constituents of soils and their determination especially from a physical-chemical point of view.

In February, 1904, Mr. A. W. Bosworth was appointed Assistant in charge of the special investigation into the chemistry of the manufacture of soft cheeses, under my direction, and for two months he worked with Professor L. B. Mendel at the Sheffield Scientific School at Yale. Quantitative analyses of Roquefort and Camembert cheeses and some preliminary investigations into the qualitative nature of their composition and of the products of growth of moulds isolated from them have been made.

As far as my other duties allowed, I have carried out analyses of samples from feeding and other experiments of the Station, and a few for outside persons, in which work I have had some assistance from Mr. F. G. Jackson and H. D. Edmond. I have analyzed seven samples of milk, eight feeds, two samples of the flesh of animals fed on experimental rations, three samples of potatoes, and two of fertilizers; in all, twenty-two samples, comprising determinations of 75 separate constituents. A report on analyses to determine the effect of a silage ration on the acidity of milk appears elsewhere.

Respectfully submitted,

B. BERNARD TURNER.

Report of the Assistant Bacteriologist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The bacteriological work in which I have been engaged during the past year has been along a number of different lines. The results of some of the investigations appear in this report, others will be published later in bulletin form, while still others form part of a series of experiments which are not yet complete and the results of which it seems best not to publish until the special investigation has been completed. Much of the work done during the past year is included under this last head.

An extended study is being made of the occurrence and distribution of bacteria in the udder of the cow. This study includes a determination not only of the numbers but of the species and their effect upon milk. This means a large amount of work before anything like a complete line of experiment can be finished. Parallel to this work, a similar study is being made of the organisms found existing in and about the stables. At the same time a similar series of investigations is being made in regard to the organisms found upon the various feeds commonly fed to dairy cows. These three lines of experiment are still in progress, and the results will be published later.

During the year one of the largest milk producers in the state was troubled with the occurrence of slimy milk, which threatened to cause great financial loss. He applied to the Station for assistance, and this department investigated the trouble, with the result that the organism causing the slimy condition of the milk was eliminated, and there has been no recurrence of the trouble since.

In response to the offer made by Director Clinton at the State Dairymen's meeting last winter, the Station has received a number of requests to have farms inspected. Eight dairymen have availed themselves of the offer, and these farms have been visited and such suggestions given as seemed advisable. Some work has been done to determine the effect of the centrifugal separator upon the germ content and keeping qualities of milk.

Another line of work which has been carried on is the testing for bacterial content and dirt contamination of the milk of a number of milkmen as it was delivered to the consumer. Considerable study has been given during the past few months to stable conditions as affecting the quality of milk. This work is not yet completed, but the results obtained thus far will soon be published by the Station in bulletin form.

Respectfully submitted,

W. A. STOCKING, JR.

Report of the Mycologist.

To the Director of the Storrs Agricultural Experiment Station:

SIR:—The mycologist of the cheese investigation began work March 7, 1904. The problem of the relation of fungi to the making and curing of cheese has developed several necessary lines of study. Primarily it was necessary to isolate and cultivate all fungi found upon the imported cheeses in question, and to do this from a sufficient number of specimens to establish a reasonable certainty that we had cultures of all forms concerned. To carry on experimental work upon the making of cheese it became necessary also to isolate, cultivate, and identify all forms occurring in connection with the dairy and the laboratories in which the investigation is pursued. This has brought into pure culture about thirty-five species of mold, which must be figured and described and identified as far as possible. To these have been added a few related forms occurring elsewhere, but tending by comparison to assist in our task.

The more important work, however, has been the study by many carefully devised and accurately recorded experiments, of the physiological effects upon milk and curd of the new forms always present in Camembert and Roquefort cheese. These studies are still in progress.

Respectfully submitted,

CHARLES THOM.

THE EFFECT OF DIFFERENT TEMPERATURES IN DETERMINING THE SPECIES OF BACTERIA WHICH GROW IN MILK.

BY H. W. CONN AND W. M. ESTEN.

[Acknowledgment is hereby made to the Rockefeller Institute for assistance in carrying out the experiments here described.]

For the last three years work has been done in this laboratory upon the relation of the growth of bacteria in milk to a variety of conditions. Several previous reports of this work have been published in the last two years (Ann. Rep. of Storrs Sta. 1901, 1902–3. Rev. Gen. a. Lait, vol. I., 1901, vol. II., 1903). The most important conclusions reached in the work hitherto reported have been: 1. At the temperature of 20° C. the common *Bacterium acidi lactis* grows with especial rapidity, and seems to be more favored by this temperature than is any other species. 2. At 13° C. the ordinary acid organisms do not grow so readily as at 20° C., but other species of bacteria do develop readily. 3. The percentage of acid bacteria increases with the total number of bacteria in ordinary market milk, provided that milk is kept at moderately warm temperatures. From the last fact it has been suggested that by a qualitative analysis, which will detect the percentage of the ordinary lactic bacteria, it is possible to determine whether a sample of market milk that contains large numbers of bacteria is old and has been kept at a low temperature, or whether it is fresher but has been kept at a higher temperature. Experiments upon the effect of temperature upon bacterial growth have been extended and carried on in more detail and with greater care during the last year. The purpose of these experiments, reported in this paper, has been: 1, to extend the observations of the effect of temperature upon the species of bacteria which grow in milk, so as to include a wider range of temperatures; 2, to determine whether there is any regularity in the results.

The significance of the questions thus studied is considerable. Their bearing upon the hygienic problems of milk will be recognized when it is remembered that normal lactic bacteria are quite harmless to health, and that the troubles attributed to milk bacteria must be associated with other species. The development of lactic bacteria has been shown to check the growth of other species. Hence it follows that conditions favoring the growth of lactic bacteria may actually make the milk more, rather than less, wholesome; while conditions that check their growth may favor the development of other more harmful bacteria, and, while preserving the milk from souring, actually render it less wholesome. It has actually been suggested by Bernstein (Milchztg., 1904, p. 133) that the most healthful method of treating milk for public consumption is to destroy its bacteria by pasteurization and then to inoculate it with a heavy culture of lactic bacteria. The ordinary method of preserving milk is by the use of low temperatures, and it becomes needful, therefore, to learn exactly what effect the low temperatures have upon the milk bacteria, not upon numbers simply, but upon species.

The bearing of these facts upon dairy problems is no less close. It is known that certain dairy species are useful to the butter maker and necessary to the cheese maker, while others are deleterious. Some species ruin the taste of butter, and others fill cheese with gas, producing the "gassy curd" and "swelled cheese" which the cheese maker so much dreads. To check the growth of these species and to favor the growth of the desired types is the object of controlling dairy conditions. The close relation of these problems to temperature makes it especially desirable to know what effect variation in temperature has upon the growth of different types of bacteria. It is for the purpose of obtaining light upon the two problems, the one of the dairy and the other of public hygiene, that the long series of experiments outlined in this paper were undertaken; and the importance of the problems gives value to the results, even though, for reasons to be explained, the results can as yet be regarded as only approximately accurate.

METHODS.

The methods of experimenting used in the experiments described below are, briefly, as follows. Milk which has been used for the purpose has been ordinary market milk, obtained from one of the milk dealers in Middletown. The dealer in question keeps his dairy in a rather exceptionally good condition, and the milk which he furnishes is above the average. It is quite fresh when delivered from the cart, being only one or two hours old, and contains, as will be seen from the experiments, a rather small number of bacteria, usually about 20,000 per cubic centimeter. Our experiments thus far comprise two series. In the first the milk was divided at once into three lots, a series of bacteriological plates made immediately from the milk, and then the three samples placed at different temperatures. They were again subsequently plated at regular intervals until they curdled. The temperatures chosen for the first series of experiments were 37° C., 20° C., and 10° C.; these temperatures representing body temperature, or hot summer heat, the temperature of an ordinary room, and that of an ice chest. In the second series of experiments the temperatures chosen were 20° C., 10° C., and 1° C. It would have been preferable to use all four temperatures with the same lot of milk, but this would have increased the number of plates to be studied so greatly as to make it impracticable to handle them all at the same time. The intervals chosen for making the bacteriological analyses were necessarily different for the three samples. In the milk kept at 37° C., the development of bacteria was very much more rapid than in either of the other samples. This made it necessary to analyze the warmer sample of milk at much more frequent intervals than the cooler samples. On the other hand, the bacteria in the milk kept at 10° C. developed very slowly, and a very much longer interval between the different analyses was necessary to make them at all comparable to the tests of the other two samples of milk. It required considerable preliminary experimenting before it was possible to determine at what intervals the different tests should be made in the different samples. The purpose was to obtain tests at such intervals that the development of the bacteria should be as closely as possible parallel in the three tests, *so far as concerns numbers*. The great irregularity in the rapidity of

multiplication of bacteria, even at the same temperature, as shown in the following tables, made it impossible to choose intervals that corresponded exactly in different experiments. After some preliminary tests it was found that the best intervals were as follows: Milk kept at 37° C. was plated every 2 hours; that kept at 20° C. every 6 hours; that kept at 10° C. every 12 hours; and that kept at 1° C. about every 3 days.

In making plates for analyses it was always necessary to dilute the milk with sterilized water. Here arose the greatest problem in the series of experiments, and one which was never solved with perfect satisfaction, since it was not possible to be sure that the dilution chosen would be the proper one for the purpose of analysis. Experience has shown us that, in order to make a differential analysis of species, it is desirable to have from 200 to 500 colonies on each plate. If the number is higher than that, the differentiation is unsatisfactory, since the colonies look so much alike when crowded; if the number is lower than 200, the analysis cannot be regarded as a fair sample, and species present in small numbers will be missed entirely. The proper dilution to obtain this number of colonies on the plate varied, of course, with the number of bacteria in the milk. If the bacteria multiplied with the same rapidity in all samples kept at the same temperature, it would, of course, be possible, after some experience, to determine quite closely the desired dilution. But since the different samples of milk contained at the outset different numbers, and since the rate of multiplication at the same temperature varied in the different samples, and inasmuch as it was never possible to determine with accuracy how many bacteria were to be expected, in many cases the proper dilution was not obtained, and many experiments were rendered useless by this fact. We first carried through several experiments simply for the purpose of determining the numbers of bacteria, and then, from the general average of the numbers of bacteria in these preliminary experiments, made as close an approximation as possible to the proper dilution, at different hours, for producing from 200 to 500 colonies to the plate. Where the bacteria in the later samples developed either more or less rapidly than in the preliminary tests, the dilutions did not come out satisfactorily. As a result, in the experiments described, a somewhat unequal value must

be placed upon the differentiation of species. In some cases, where, as noted in the tables, the dilution was too high, and in some cases, where it was too low, the results are of less value than in other cases. This discrepancy has thus far been unavoidable, and although it makes the results somewhat irregular, nevertheless, since in each series only a few of the tests were thus unreliable, the conclusions as to the general tendency of the results obtained were not materially vitiated by them. In the tables given below it will be seen that some of the analyses are wholly omitted because untrustworthy, and that considerable irregularities are shown in other cases. Hence, no individual analyses can be strictly relied upon, although the general course of development of species is probably reliable; a fact proved by the general agreement of the different experiments. In our experiments we planned to make at least three plates from each sample tested, and these three were always made with different dilutions. By this means one of the three was usually of a proper dilution, even if the others were not. Sometimes all three plates were usable, at other times only one was satisfactory.

The culture medium used for analyses was that described in our previous report. It was usually a mixture of ordinary peptone gelatin, containing milk sugar, and gelatin made from whey as previously described. A mixture of half peptone and half whey gelatin was found to be most satisfactory. These materials were prepared as described in a previous report, with a little higher percentage of the ingredients than usual in such media, so that when subsequently diluted with one-fourth their bulk of litmus solution, the result was to obtain a medium with ordinary percentages. Eight cubic centimeters of this more highly concentrated culture medium was placed in test tubes and sterilized. At the time of using, two cubic centimeters of sterile blue litmus solution was added to each test tube. The result was a deep blue gelatin, upon which the acid bacteria were readily differentiated, and which, as described in a previous report, gave a possibility of considerable differentiation among the colonies, sufficient at least to differentiate *types* of bacteria, though not, as a rule, accurate enough to separate species.

The plates thus made were allowed to develop, if possible, at room temperature for five or six days, or a week, inasmuch as the differentiation of the bacteria from the appearance of their

colonies is satisfactory only after this length of time. In a few instances, where the liquefiers were too abundant, it was impossible to keep the plates so long, and the results obtained were unreliable; but in most of the experiments here recorded the plates were about six days old when studied, and differentiation was therefore as satisfactory as possible. Three and sometimes four plates were made at each test, and the results were averaged.

In the study of the plates the total number of bacteria was determined, and then the total number of different types of colonies that could be differentiated from each other by the use of a hand lens and a low power microscope. This differentiation of the colonies on the plate is the crucial point in the series of experiments, and the value of the conclusions depends upon the reliability of the differentiations. It was found possible to distinguish without much difficulty about fifteen different groups of bacteria, by which is meant, of course, the number of types of distinguishable colonies in litmus gelatin. A considerably larger number can readily be distinguished, but outside of these chief types the bacteria found are only isolated colonies, and play no special part in the problems under consideration. The groups tabulated are, as stated, separated from each other wholly by the character of their colonies upon litmus gelatin. We have made many further tests of these groups by isolating colonies of each type and carrying them through a long series of cultures, to determine whether our types represented single species or groups of several celled species. These results are not yet ready for publication. In general we find that the types are commonly groups of several species; some, indeed, are quite complex. Some of these facts are briefly given in the following description of types.

GROUP I. *Bacterium lactis acidi* (Leichman–Esten). This species, as shown by Esten (An. Rep. Storrs Exp. Sta., 1896) is the lactic bacterium of our dairies *par excellence*, and needs no description. There seem to be several varieties of the species, some of which are capable of curdling milk, and others not. Our many tests of this species show us that a majority of the cultures of this type, isolated and tested, fail to curdle sterilized milk at 20°C. All produce acid, however, and all

agree in cultural characters. We regard them simply as physiological varieties of the same species. They produce a small opaque red colony with minute spines on its edge. The colonies never grow on the surface, and grow better under a mica plate. The cultures in general grow better if they are not exposed to the air. Some of the cultures which are grouped under this head are Streptococci, and thus clearly belong to different species from the others, although their reaction upon milk and other culture media appears to be identical with that of *Bacterium lactis acidi*.

GROUP II. *Bacterium lactis acidi II.* This, as mentioned in a previous report, differs from Group I. only in its colony. The litmus gelatin colony is extremely minute, hardly visible to the naked eye, more transparent than the colony of Group I., and never shows the spiny edge. We are inclined to believe that it is only a type of Group I., and that the differences in colony are due to conditions not yet understood. Sometimes, for several months in succession, Group II. will be wholly wanting.

Groups I. and II. constitute the typical lactic bacteria which sour milk in the vast majority of cases.

GROUP III. *Bacterium lactis aerogenes*, etc. This type produces a colony of large size, brilliantly red in litmus gelatin, growing on the surface as well as below, and frequently producing gas. When these colonies are isolated they prove to be, usually, *Bacterium lactis aerogenes*. Occasionally they are *B. coli communis*, as shown by their possessing flagella.

To differentiate between these two species by their colonies has hitherto been found impossible. In a very few instances colonies isolated as of this type have shown a slight power of liquefying gelatin. This is very unusual. The amount of gas produced in dextrose broth varies widely. In some few instances the cultures fail to produce gas, while in others the gas produced is enormous. These gas producing species cause great trouble in the dairy, and their development in milk is, therefore, a matter of much interest, since any conditions that stimulate their growth are almost sure to injure the milk for dairy purposes.

GROUP IV. *Neutral bacteria.* This is the least satisfactorily determined of all our types. It includes the colonies that show no acid reaction and no distinctive characters. They are usually opaque, and grow readily both upon the surface of gelatin and below. Such characters are mostly negative, and it is to be expected that the group will include a considerable variety of species. We have isolated and studied a large number of these, and find several distinct bacteria that are grouped under this type of colony. Some are cocci, some are rods. They include Nos. 194, 198, and 205 of our published list (An. Rep. of Storrs Exp. Sta., 1895) and some other species which will be described in a later report. From the standpoint of their relations to milk they are of little importance, since they agree in having no noticeable effect upon milk under any conditions. We regard them, therefore, as neutral species. As seen from the following tables, they always comprise a large percentage of the bacteria in fresh milk and in older milk which has been kept at a low temperature. Whether they are of significance from a hygienic standpoint we have not yet determined. Experiments are being undertaken at the present time to determine whether these organisms have any pathogenic properties. No pathogenic action upon guinea pigs has yet been determined, but the work is still too incomplete to justify any final conclusions. From the dairyman's standpoint this group is quite neutral, since it produces no effect upon dairy products. Whether any members of the group are significant from the standpoint of the wholesomeness of the milk remains for further experiments to determine. In our discussion of the results, given in the following pages, we shall refer to this group as the neutral bacteria.

GROUP V. *Yellow bacteria.* This group includes colonies with a brilliant yellow color. Such a general description will naturally include many different species of bacteria, but nearly all those found in milk, in this vicinity, which produce the yellow color prove to be Sarcina. We have isolated many colonies of this type, and found them in nearly every case of the Sarcina type. The group is of little importance for our study, since, although nearly always present in small numbers at the outset, they almost universally disappear after a few hours, and

never multiply to any considerable extent. They have little or no effect upon milk, and do not contribute to the changes which occur in milk after it has been kept for some time.

GROUP VI. *Rapid liquefiers.* This group includes several species, all characterized by a very rapid liquefaction of gelatin. Frequently a single colony may spread so rapidly as to destroy a plate in two or three days. It includes *B. subtilis*, *B. mycoides*, and their allies, and comprises species which are commonly putrefactive in their action. It is a group of considerable significance because of its rapid decomposing action on milk. Fortunately it is never present in very great abundance.

GROUP VII. *Slow liquefiers.* The members of this group are not always clearly separated from those of Group VI. They liquefy gelatin plates slowly and incompletely, the colonies even after several days being rarely more than 1 centimeter in diameter, and frequently even smaller. Their putrefactive power is less, as indicated by a less offensive odor. All, of course, produce digestive enzyms, and consequently show a decomposing action upon milk, although this action is not always very noticeable. Several species of bacteria are here included. In each sample of milk, however, this group commonly includes only a single species, although sometimes two or three species of slow liquefiers are found in the same sample of milk.

Because of their decomposing action upon milk and their tendency to produce putrefaction, we regard the last two types of bacteria as of much significance. They always tend to produce decomposition of the proteids in the milk, and their presence in milk is always undesirable. Any conditions that encourage their growth are to be avoided, while conditions that check them are to be desired.

GROUP VIII. *Pale thin colonies.* These do not represent a single species, but in nearly every case where they have been tested they prove to be very difficult to cultivate in artificial media and to have no effect on milk. They occur only in small numbers.

GROUP IX. *Red brown colonies.* These were found in small numbers only, and in only a few samples of milk.

Neither Group VIII. nor IX. has seemed to be of any significance in our studies, since both disappear rapidly from the milk.

In next to the last column of our tables we have placed the few miscellaneous species found sporadically in different samples. Frequently these have been clearly distinguished and separately enumerated in our studies of the plates, but since they are present in small numbers only and are likewise sporadic in the different samples, we have not regarded it as necessary to tabulate them specially. In this column, also, are included the undetermined colonies. In our study of the plates we first determined the total number of colonies, then the number of colonies of each clearly distinguished group. The difference between the sum of these distinguishable colonies and the total numbers gave the number of indeterminate colonies. As will be seen by the tables that follow, it was possible in some cases to differentiate practically all of the colonies, so that the number of undetermined was zero; while in others the differentiation was more difficult, and this number was high. The accuracy of the differentiation of the group thus varies inversely with the percentage of the undetermined colonies. Whenever this number is high, it has generally been due to the difficulty of distinguishing between the neutral bacteria and the lactic bacteria of Groups I. and II. Usually most of the undetermined should be added to Group I., since they were commonly faintly acid colonies, not clearly distinguishable as *Bact. lactis acidi.* A closer approximation to a correct result may thus usually be obtained by adding the first and the next to the last columns.

In the tables that follow, both total numbers and percentage are given. In giving the total numbers only the significant numbers are recorded. If the number is under 1,000, it is given to the nearest 100; if over 100,000, it is given to the nearest 10,000; if over 1,000,000, to the nearest 100,000; and if over 10,000,000, to the nearest 1,000,000 only. The percentage is printed in black faced type, and is calculated to the nearest tenth of one per cent. This close calculation was necessary to bring into the tables at all some of the groups present in small numbers only, for these were frequently found in numbers representing less than one per cent.

EXPERIMENT NO. I. FEBRUARY 2.

This experiment was merely a preliminary one, designed to give an idea of the numbers of bacteria to be expected and the necessary dilution. Only a single plate was made at each test, and the results are, therefore, not very trustworthy. But since the growth of bacteria agreed in general with that of the later and more accurate experiments, the results are given here. Milk was obtained at 8 A. M. and divided, as described, into three lots. The milk kept at 37° curdled in 16 hours; that kept at 20° curdled in 40 hours; the sample kept at 12° did not curdle in 96 hours, but at the end of the experiment was somewhat thickened, and had a pleasant butter aroma. Tables 1, 2, and 3 represent the results of the analyses of the sample at different periods.

In these tables the following chief points are to be noted:

Milk kept at 12°.—1. The increase in bacteria during the experiment was chiefly in Group IV., the group of neutral bacteria. The number at the end of 4 days became very high, over 1,300,000,000 per cubic centimeter; but in spite of this large number the milk was not curdled.

2. Along with this great development of neutral bacteria the lactic bacteria developed appreciably, and there were about 20,000,000 per cubic centimeter of the first two groups at the end of the experiment.

3. The liquefiers continued to grow through the whole period.

The failure to obtain a proper dilution made the last tests unsatisfactory.

Milk kept at 20°.—1. A striking contrast is seen between this and the 12° milk. The neutral group IV. developed only moderately, reaching the number of 97,000,000 in 24 hours, after which they slightly declined.

2. The chief growth of bacteria at this temperature was the Group I., that is, *B. lactis acidi*, and Group II., which may be the same species. These two comprised over 93 per cent. of all bacteria present at the 36th hour.

3. All others disappeared except a few stragglers of *B. aerogenes*—Group III.—and a very small number of liquefiers.

Table I.

Bacterial development in milk kept at 12° C.

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
0,	2,000 5.1	400 1.	—	12,800 32.8	4,000 10.2	—	6,900 17.6	2,500 6.4	2,400 6.1	8,100 20.8	39,000
12,	2,500 5.9	8,000 18.7	100 .2	19,000 44.8	2,400 6.8	—	5,000 11.7	5,000 11.9	—	—	43,000
24,	11,200 5.7	4,800 2.4	1,200 .6	160,000 80.4	—	500 .3	1,800 .9	19,000 9.7	—	—	199,000
36,*	—	—	—	—	—	—	—	—	—	—	—
48,*	—	—	—	—	—	—	—	—	—	—	—
60,	5,000,000 1.5	—	250,000 ?	352,000,000 97.8	—	1,750,000 .5	750,000 .2	—	—	—	360,000,000
72,	43,000,000 9.4		300,000 ?	406,000,000 89.2	—	4,500,000 .9	2,100,000 .5	—	—	—	456,000,000
84,	6,000,000 .5		500,000 ?	1,121,000,000 98.7	—	5,500,000 .5	3,000,000 .3	*	*	—	1,136,000,000
96,	20,000,000 1.5		1,000,000 ?	1,322,000,000 96.1	—	6,000,000 .5	3,000,000 .2	*	*	24,000,000 1.7	1,376,000,000

*Dilution too low, groups not properly separated.

TABLE 2.

Bacterial development in milk kept at 20° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
6, - -	5,000 **7.8**	3,200 **5.**	600 **.9**	14,000 **21.9**	3,200 **5.1**	200 **.3**	8,400 **13.1**	6,800 **10.6**	2,600 **4.**	20,000 **31.3**	64,000
12, - -	60,000 **5.**	3,300 **.2**	—	1,100,000 **93.3**	—	—	30,000 **2.5**	—	—	—	1,200,000
18, - -	6,300,000 **47.3**	—	40,000 **.3**	5,800,000 **43.5**	—	—	600,000 **4.6**	—	—	600,000 **4.3**	14,000,000
24, - -	33,000,000 **21.6**	4,000,000 **2.6**	250,000 **.2**	97,000,000 **63.**	750,000 **.4**	250,000 **.2**	5,000,000 **3.2**	3,500,000 **2.2**	—	10,000,000 **6.6**	13,000,000
30, - -	274,000,000 **74.4**	44,000,000 **12.1**	1,600,000 **.4**	46,000,000 **12.5**	—	400,000 **.1**	2,000,000 **.5**	—	—	—	155,000,000
36, - -	845,000,000 **74.4**	213,000,000 **18.8**	4,800,000 **.4**	69,000,000 **6.2**	—	—	2,000,000 **.2**	—	—	—	1,134,000,000

TABLE 3.

Bacterial development in milk kept at 37° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
2, - -	1,200 **2.8**	1,200 **2.8**	—	15,000 **36.2**	4,000 **9.7**	—	8,000 **19.5**	3,900 **9.9**	5,800 **14.1**	2,100 **5.**	41,000
4, - -	5,800 **2.3**	64,000 **25.1**	400 **.2**	8,800 **3.5**	1,400 **.5**	—	77,000 **30.9**	1,600 **.6**	—	90,000 **36.3**	250,000
6, - -	54,000 **1.**	5,000,000 **97.5**	2,800 **?**	—	—	2,800 **?**	80,000 **1.5**	—	—	—	5,200,000
8, - -	19,000,000 **98.7**		66,000 **.3**	—	—	195,000 **1.**		—	—	—	19,000,000
10,* - -	—	—	—	—	—	—	—	—	—	—	—
12,† - -	—	—	—	—	—	—	—	—	—	—	—
14, - -	6,000,000 **4.5**	20,000,000 **15.5**	91,000,000 **68.**	900,000 **.7**	—	—	7,500,000 **5.7**	—	—	730,000 **5.6**	132,000,000

* Dilution too low.

† Dilution too low. Liquefiers very abundant.

Milk kept at 37°.—1. Although there was at first a noticeable development of the acid organisms, Groups I. and II. in the later hours Group III., *B. aerogenes*, developed very much more rapidly. At the last test, just before curdling, Group III. had far outgrown all other species, and while Groups I. and II. were still quite numerous, the *B. aerogenes* had taken the lead, and constituted 68 per cent.

2. The total numbers present at the time of curdling were very much less than in the samples kept at either 10° or 20°.

EXPERIMENT NO. 2, FEBRUARY 13.

This experiment was a repetition of the first, except that a larger number of plates were made at each test, of different dilutions, and the results, representing an average of several analyses, are more reliable than those of experiment 1. The milk was at a temperature of 7° when obtained (2 hours old). Plates were made of it at once, and samples placed at 12°, 20°, and 37°, and plated at intervals shown in the tables. The milk kept at 37° curdled in 18 hours, with a tough broken curd and much gas. That kept at 20° curdled in 56 hours. That kept at 12° curdled in 9½ days. Analyses of the last were made up to the 196th hour. The details of the analyses are shown in Tables 4, 5, and 6.

The three analyses of milk at 12°, taken at the end of 46, 60, and 70 hours, show the results of too high a dilution, the number of colonies on a plate being only from 10 to 30 in the different samples. It will be noticed that in these three plates only three of the different groups were detected. This was due to the fact that the dilution was so high that an average sample was not obtained, and the only species that appeared were those present in the largest numbers. The three analyses, therefore, show us what types were present in the largest numbers, but do not give any evidence of those present in smaller numbers, and do not give us the proper analysis of the milk at these periods.

From the tables the following points are to be noted:

Milk kept at 12°.—1. There was a slight decline in total numbers until about the 40th hour.

TABLE 4.—*Bacterial development in milk kept at 12° C.*

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
0, - -	1,000 3.5	1,600 5.7	—	12,750 44.5	1,575 5.4	150 .2	5,000 17.3	1,150 3.9	1,100 3.7	4,500 15.8	29,000
12, - -	1,500 5.2	3,200 11.2	—	10,700 37.4	1,400 4.9	—	5,800 20.3	1,000 3.5	1,200 4.2	3,800 13.3	29,000
24, - -	2,700 12.5	—	—	11,000 45.8	960 4.1	1,350 5.6	2,600 11.1	1,350 5.6	2,000 8.4	1,900 7.9	24,000
36, - -	10,000 5.6	—	4,400 2.7	77,000 48.2	4,400 2.8	—	48,000 26.5	—	—	23,700 14.2	17,000
48, - -	—	—	—	2,000,000 85.	—	100,000 3.3	355,000 11.7	*	*	*	*
60, - -	—	—	—	19,000,000 71.4	—	5,000,000 18.1	3,000,000 10.5	*	*	*	*
72, - -	—	—	—	43,000,000 69.6	—	8,100,000 12.5	10,000,000 15.5	1,500,000 2.4	*	*	*
84, - -	300,000 .3	240,000 2.5	—	64,009,000 67.	—	8,100,000 8.5	13,000,000 12.2	6,000,000 6.3	—	3,000,000 3.2	97,000,000
96, - -	23,000,000 13.	— ?	1,200,000 1.	92,000,000 53.3	—	9,200,000 5.5	20,000,000 10.8	5,600,000 3.4	12,000,000 7.4	8,800,000 5.6	173,000,000
120, - -	34,000,000 12.2	—	—	91,000,000 35.	—	52,000,000 20.2	28,000,000 11.	—	13,000,000 5.2	44,000,000 16.4	262,000,000
148, - -	60,000,000 14.4	—	5,000,000 1.	151,000,000 36.2	—	54,000,000 13.	42,000,000 11.3	2,000,000 .5	—	99,000,000 23.6	413,000,000
172, - -	78,000,000 13.9	—	4,000,000 .7	338,000,000 59.9	—	146,000,000 25.		—	—	2,800,000 .5	568,000,000
196, - -	96,000,000 24.2	—	3,000,000 .7	162,000,000 40.	—	25,000,000 6.	40,000,000 9.8	5,000,000 1.3	2,000,000 .6	69,000,000 17.4	402,000,000

* Dilution too high.

TABLE 5.

Bacterial development in milk kept at 20° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
6, - -	700 **3.8**	—	—	11,700 **58.4**	1,800 **6.3**	700 **3.3**	1,700 **8.5**	1,200 **6.**	—	2,800 **13.7**	21,000
12, - -	59,500 **6.4**	240,000 **26.**	—	104,000 **11.3**	—	5,000 **.6**	11,500 **1.2**	22,000 **2.5**	27,000 **2.9**	450,000 **49.1**	920,000
18, - -	310,000 **14.7**	—	—	1,350,000 **65.1**	—	230,000 **10.8**	—	65,000 **3.1**	—	130,000 **6.3**	2,100,000
24, - -	12,000,000 **31.7**	—	400,000 **1.1**	16,000,000 **41.8**	—	1,650,000 **4.1**	250,000 **.6**	3,000,000 **8.**	—	5,000,000 **12.7**	38,000,000
30, - -	315,000,000 **76.5**	20,000,000 **4.7**	500,000 **.1**	66,000,000 **16.**	—	1,250,000 **.3**	—	10,000,000 **2.4**	—	—	413,000,000
36, - -	824,000,000 **75.**	104,000,000 **9.1**	4,000,000 **2.5**	137,000,000 **12.8**	—	1,500,000 **.2**	1,000,000 **.1**	—	—	—	1,072,000,000
48, - -	816,000,000 **52.**	688,000,000 **46.8**	6,000,000 **.4**	8,000,000 **.6**	—	—	—	—	—	—	1,518,000,000
54, - -	512,000,000 **34.9**	952,000,000 **64.8**	4,000,000 **.3**	—	—	—	—	—	—	—	1,468,000,000

TABLE 6.

Bacterial development in milk kept at 37° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
2, - - - - -	1,100 4.5	7,700 22.4	—	8,000 2.9	1,000 3.7	—	3,800 14.8	850 2.6	350 .9	6,300*b* 22.1	29,000
4, - - - - -	1,500 10.7	—	—	8,700 51.5	500 3.5	500 3.5	4,000 23.6	1,000 7.2	—	—	16,000
6, - - - - -	16,000 1.4	624,000 55.9	1,000 1.	1,000 1.	1,000 1.	2,000 .2	1,000 .1	64,000 5.	—	480,000*a* 37.	1,200,000
8, - - - - -	2,000,000 40.5	790,000 15.4	—	—	—	—	12,000 .3	—	—	2,500,000*a* 43.8	5,300,000
10, - - - - -	1,300,000 5.5	800,000 2.4	100,000 .3	—	—	—	160,000 .6	600,000 1.8	—	23,000,000*a* 83.4	26,000,000
12, - - - - -	36,000,000 5.4	17,000,000 38.5	200,000 .3	—	—		4,000,000 7.	—	—	—	57,000,000
14, - - - - -	38,000,000 21.4	131,000,000 7.3	800,000 .5	3,000,000 2.1	—		3,000,000 1.7	2,000,000 1.3	—	—	177,000,000
16, - - - - -	187,000,000 50.8	170,000,000 45.6	11,000,000 3.0	—	—	—	1,000,000 .3	—	—	1,000,000 .3	370,000,000

(*a*) In these plates it was impossible to differentiate all colonies of Groups I., II., and IV., and hence they are placed together in the column of undetermined.

(*b*) This number of 6,300 bacteria included six distinguishable species of bacteria, besides those that belonged to Groups I. and IV., which were not sharply differentiated.

2. In this milk nearly every species present in the original milk developed and was present at the close, each showing quite a high percentage, even at the end of the experiment. Group V. disappears entirely, and Group II. apparently so. All the others are present in almost as large percentage at the end as at the start.

3. The chief development of bacteria in this sample was due to Group IV., the neutral bacteria, which increased in numbers to 328,000,000 per cubic centimeter, after which there was a slight decline. Group I., the normal acid bacteria, also developed abundantly; but the increase in numbers of this group did not begin until about 4 days after the beginning of the experiments. After this there was a regular increase up to 96,000,000, constituting about 24 per cent.

4. The development of the liquefying bacteria was especially striking. They increased with more or less constancy through the whole experiment, and toward the end comprised about a quarter of all the bacteria present. In the last experiment there was a slight decline in numbers.

Milk kept at 20°.—1. At 20° a very different result is seen. The bacteria began to grow rapidly just before the 12th hour, and the chief growth from this time on was due to the lactic bacteria—Groups I. and II.—which in the end comprised over 99 per cent. of all species.

2. The liquefying bacteria in this case were rapidly excluded from the milk, and were not found in the experiment after 36 hours.

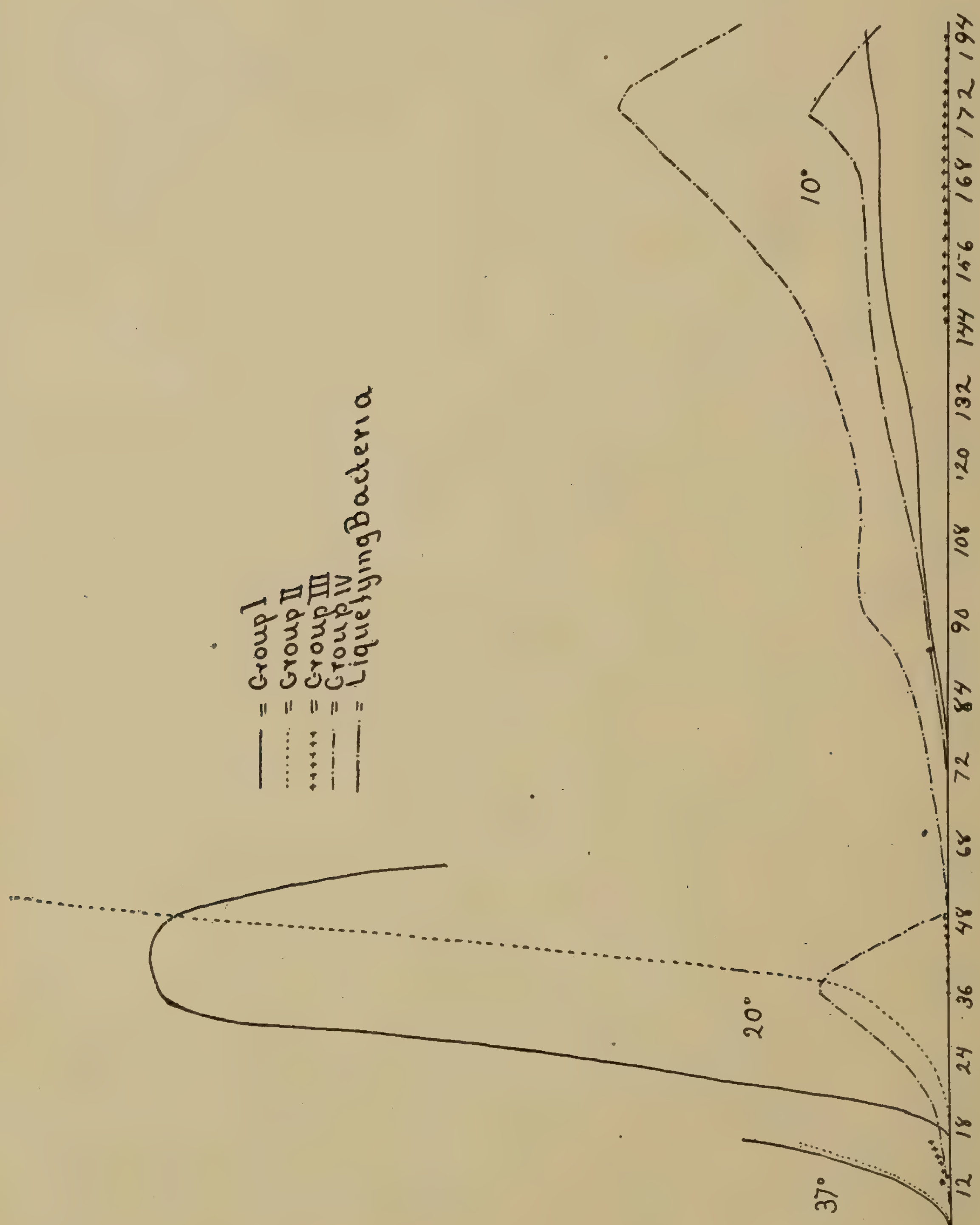
3. Group III., *B. aerogenes*, developed slightly, but even at the end only composed 0.3 per cent. of all the bacteria.

Milk kept at 37°.—1. At 37° the results were in some respects similar to those at 70°, for here also the two groups, I. and II., comprised at the end a large majority of the bacteria—about 96 per cent. There was, however, at this temperature a larger per cent. of Group III., namely, 3 per cent., or about 11,000,000 per cubic centimeter.

2. It will be noticed also that the liquefiers remained in considerable numbers to the end of this experiment, not being wholly excluded as they were at 20°. The neutral group, IV.,

did not show itself in this sample of milk after the first few hours, and evidently played no important part in the changes that took place in the milk. The differentiation of Groups I. and IV. was, however, not satisfactory.

PLATE I.



The results of this experiment are shown graphically in Plate 1. In this and the following plates only the five chief types of bacteria are represented.

EXPERIMENT NO. 3, APRIL 20.

The conditions of this experiment were identical with those of the preceding. The sample of milk kept at 37° curdled in 18 hours, that kept at 20° curdled in about 40 hours (in the

PLATE 2.

night), and that kept at 10° curdled in 13 days. The detailed results are shown in tables 7–9. Plate II. shows graphically the facts brought out by the tables.

TABLE 7.

Bacterial development in milk kept at 10° C.

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX,	Miscellaneous and Undetermined.	Total.
0, -	1,100 **2.3**	67 **.1**	—	25,000 **52.2**	1,200 **2.5**	100 **.2**	2,500 **5.4**	3,700 **8.2**	—	14,000 **29.1**	48,000
12, -	800 **1.8**	600 **1.1**	150 **.3**	29,000 **64.0**	600 **1.4**	—	2,900 **5.9**	4,400 **10.5**	—	6,500 **15.0**	45,000
24, -	2,000 **6.1**	—	400 **1.2**	16,000 **49.7**	800 **2.4**	—	1,200 **3.6**	3,600 **11.**	—	8,600 **26.0**	33,000
36, -	60,000 **8.6**	—	28,000 **4.0**	414,000 **60.0**	16,000 **2.2**	8,000 **1.1**	78,000 **11.3**	82,000 **11.8**	—	6,000 **1.0**	692,000
48, -	20,000 **16.**	—	5,000 **8.3**	42,000 **44.9**	7,500 **3.8**	—	45,000 **23.1**	—	—	7,500 **3.9**	*
60, -	—	—	75,000 **12.5**	300,000 **58.4**	—	150,000 **29.1**	—	—	—	—	*
72, -	—	—	—	20,000,000 **60.4**	—	600,000 **17.6**	800,000 **22.0**	—	—	—	*
84, -	—	—	480,000 **2.8**	14,000,000 **83.3**	—	960,000 **5.6**	140,000 **8.3**	—	—	—	*
96, -	1,400,000 **2.2**	—	1,600,000 **2.3**	47,000,000 **68.5**	—	1,600,000 **2.3**	14,000,000 **20.2**	960,000 **1.3**	—	2,400,000 **3.2**	69,000,000
108, -	2,200,000 **1.7**	—	6,000,000 **4.6**	100,000,000 **75.8**	—	6,000,000 **4.5**	6,000,000 **4.6**	—	—	12,000,000 **8.8**	132,000,000
120, -	7,200,000 **3.7**	—	6,400,000 **3.2**	134,000,000 **68.4**	—	18,000,000 **9.3**	8,000,000 **4.2**	—	—	22,000,000 **11.2**	196,000,000

*Dilution too high.

TABLE 7.—*Continued.*

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
144, -	61,000,000	60,000,000	12,000,000	143,000,000	—	16,000,000	12,000,000	13,000,000	—	61,000,000	379,000,000
	32.0		**3.2**	**38.6**		**4.6**	**3.0**	**3.5**		**15.1**	
168, -	228,000,000	172,000,000	29,000,000	130,000,000	—	16,000,000	13,000,000	10,000,000	—	148,000,000	746,000,000
	53.4		**3.8**	**17.5**		**2.1**	**1.8**	**1.4**		**20.0**	
192, -	672,000,000	153,000,000	46,000,000	141,000,000	—	20,000,000	19,000,000	—	—	91,000,000	1,142,000,000
	72.1		**4.0**	**12.3**		**1.8**	**1.7**			**8.1**	
216, -	874,000,000	326,000,000	33,000,000	90,000,000	—	28,000,000	13,000,000	—	—	96,000,000	1,460,000,000
	82.2		**2.2**	**6.1**		**1.9**	**.9**			**6.7**	
241, -	1,128,000,000	518,000,000	38,000,000	78,000,000	—	18,000,000	14,000,000	—	—	42,000,000	1,836,000,000
	89.2		**2.0**	**4.5**		**1.0**	**.9**			**2.4**	
265, -	628,000,000	203,000,000	26,000,000	83,000,000	—	10,000,000	14,000,000	—	—	26,000,000	990,000,000
	83.8		**2.7**	**8.4**		**1.0**	**1.4**			**2.7**	
289, -	739,000,000	256,000,000	34,000,000	87,000,000	—	7,000,000	10,000,000	—	—	26,000,000	1,159,000,000
	85.7		**3.1**	**7.5**		**.6**	**.9**			**2.2**	

TABLE 8.

Bacterial development in milk kept at 20° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
6, - - - -	900 **1.9**	—	100 **.2**	32,700 **69.4**	900 **1.9**	—	6,000 **12.7**	2,300 **4.9**	—	4,300 **9.**	47,000
12, - - - -	27,000 **7.3**	—	25,000 **7.2**	200,000 **55.4**	5,000 **1.6**	5,000 **1.3**	25,000 **7.**	20,000 **5.5**	—	52,000 **15.7**	360,000
18, - - - -	503,000 **6.9**	—	395,000 **5.5**	5,400,000 **74.1**	12,000 **.2**	38,000 **.5**	290,000 **4.0**	80,000 **1.**	—	545,000 **7.8**	7,200,000
24, - - - -	5,000,000 **7.5**	—	10,000,000 **14.3**	45,000,000 **67.**	—	—	400,000 **.6**	—	—	7,000,000 **10.6**	67,000,000
30, - - - -	51,000,000 **28.5**	12,000,000†	41,000,000 **18.3**	72,000,000 **32.6**	—	375,000 **.2**	2,000,000 **1.0**	—	—	43,000,000 **19.4**	220,000,000
36, - - - -	377,000,000 **59.0**	108,000,000†	124,000,000 **16.4**	84,000,000 **10.8**	—	—	3,600,000 **.5**	—	—	93,000,000 **13.3**	792,000,000

† These are probably all the same species.

TABLE 9.

Bacterial development in milk kept at 37° C.

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
2, - - - -	850 **2.3**	—	—	21,000 **57.8**	900 **2.6**	—	2,350 **6.4**	1,750 **4.8**	—	9,000 **26.1**	36,000
4, - - - -	625 **1.2**	—	—	25,000 **30.8**	—	—	17,000 **22.2**	3,100 **2.5**	—	77,500 **43.3**	123,000
6, - - - -	5,000 **1.2**	—	5,000 **1.2**	185,000 **32.9**	—	—	280,000 **60.1**	5,000 **1.2**	—	20,000 **3.4**	500,000
8, - - - -	—	—	230,000 **15.9**	150,000 **11.0**	—	20,000 **1.6**	890,000 **63.1**	—	—	120,000 **8.4**	1,410,000
10, - - - -	—	—	27,000,000 **85.6**	2,100,000 **6.4**	—	—	2,500,000 **8.0**	—	—	—	32,000,000
12, - - - -	—	—	166,000,000 **96.5**	550,000 **.3**	—	—	5,400,000 **3.2**	—	—	—	171,000,000
14, - - - -	—	—	465,000,000 **98.6**	—	—	—	6,600,000 **1.4**	—	—	—	472,000,000
16, - - - -	—	—	569,000,000 **94.6**	—	—	—	3,100,000 **5.4**	—	—	—	572,000,000
	—	—	608,000,000 **94.1**	—	—	—	3,600,000 **5.9**	—	—	—	612,000,000

From these tables the following significant points are to be noted:

Milk kept at 10°.—1. The development of bacteria did not become noticeable for about 80 hours, although there was previous to this a slight increase. After this period a more rapid development was noticed. The chief growth of bacteria from about 60 hours until 120 hours was in the increase of Group IV. After 120 hours this group remained practically constant in numbers until about 190 hours when there was a noticeable decline, both in percentage and in actual numbers, shown best in plate II.

2. The lactic species of Groups I. and II. could not be properly differentiated in these plates, and while the tables show the separation of the two as well as it could be made, they are combined in the percentage numbers and also in Plate II. These typical lactic bacteria increased very slowly for about 120 hours, after which the increase in the two species was much more rapid, and finally the unusual number of 1,600,000,000 per cubic centimeter was found at about the 241st hour. In spite of these enormous numbers of lactic bacteria, the milk was not curdled at this time nor until the 280th hour, at which time the number of lactic bacteria had fallen off nearly one-half. The break in the curve at 265 hours (Plate II.) is doubtless an error.

3. Group III., *Bacterium aerogenes*, increased with considerable regularity in this experiment, although there was a slight decline at the end, and the percentage never became very high. The same was true of the liquefying bacteria.

4. The milk kept at 10° showed exceptionally high numbers of bacteria, for rarely does the number reach 1,000,000,000 before curdling takes place, and in this case the number rose to 1,836,000,000.

It will be noticed that Group II. appeared only in the later analyses and in a few of the first analyses. Whether this is due to the fact that this group develops only in old milk, or to the fact that it is only a modified form of Group I, we have not decided.

Milk kept at 20°.—1. Here the growth of bacteria was due largely to the lactic organisms, Groups I. and II. reaching in 36 hours a number of 500,000,000 per cubic centimeter, comprising 59 per cent. of the whole. This sample also showed a larger number of Group III. than usual, 124,000,000 per cubic centimeter, comprising 16.4 per cent.

2. The neutral bacterial group IV. continued to increase in numbers to the end, and in this respect this sample differed from the other two, in which this group disappeared in the later stages.

3. It will be noticed that the development of the lactic organisms, as before, has retarded the development of the liquefiers, which rapidly diminished in percentage although slightly increasing in numbers.

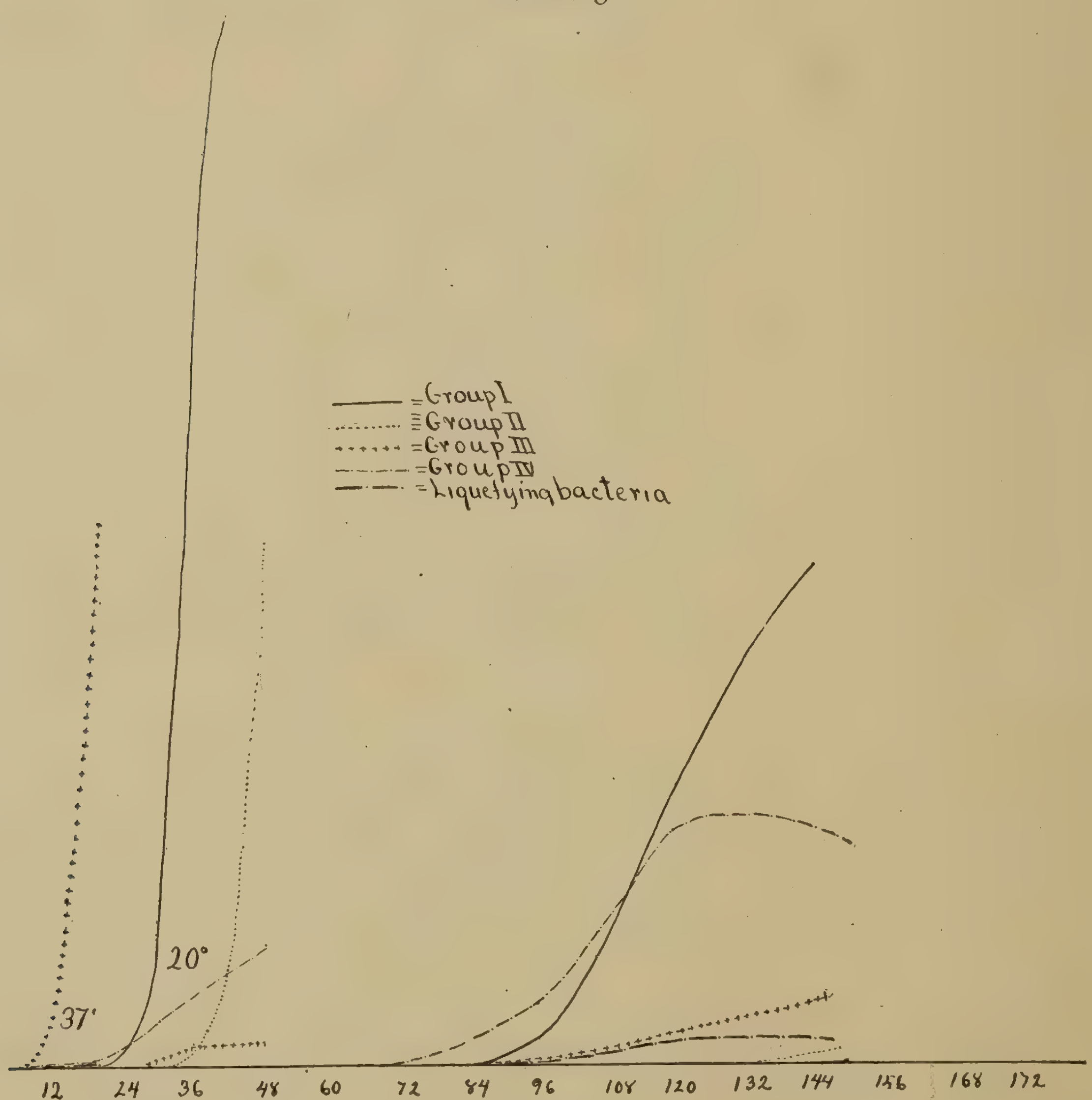
Milk kept at 37°.—1. Here the results were especially striking, inasmuch as at the time of curdling, 18 hours, the Group III., *Bacterium aerogenes*, comprised 94 per cent. of all bacteria; the only other species present at this time being a few of the liquefiers. In this sample of milk, therefore the excessive development of Group III. caused the disappearance of all others except a few liquefiers.

2. Plate 2 shows in a very striking manner the surprising effect of temperature in delaying the growth of bacteria. While at 37° the rapid development began at about the 8–10th hour, and at 20° at about the 20th hour, at 10° this growth was held back until the 72nd hour, and even then it was only the neutral bacteria that developed, the lactic species being held back until the 120th hour. The plate also shows that the neutral group and the liquefiers begin to grow first, and increase regularly until the lactic bacteria begin to be abundant, when their further increase is practically stopped. If this plate is compared with Plate 1, it will be seen that in Plate 1 where the lactic bacteria did not develop (at 10°), the other species continued to increase in numbers even to the time of curdling.

EXPERIMENT NO. 4. MAY 4.

The conditions of this experiment were identical with those of the last two. The milk curdled in 160 hours when kept at 37°, that kept at 20° curdled in 44 hours, and that kept at 10° in about 160 hours (in the night). The results were similar to those of the last experiments, but showed some striking differences. Tables 10–12 show the details of the analyses, and Plate 3 the results in a graphical manner.

PLATE 3.



The following important points are to be noted.

Milk kept at 10°.—1. The development of bacteria began rapidly at about the 72nd hour, and consisted, at first, of the growth of the neutral Group IV., which continued to develop until about the 130th hour, when its further increase was checked by the lactic bacteria.

TABLE 10.

Bacterial development in milk kept at 10° C.

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
0, - -	2,500 **4.5**	—	67 **.1**	29,300 **51.8**	2,800 **4.9**	—	3,800 **6.7**	2,167 **3.9**	—	16,000 **28.1**	57,000
12, - -	3,400 **8.8**	3,700 **9.2**	33 **.1**	18,000 **47.7**	900 **2.4**	—	1,500 **3.8**	2,200 **5.8**	—	9,000 **22.2**	39,000
24, - -	7,300 **8.2**	—	—	19,000 **64.9**	1,600 **5.5**	—	800 **2.8**	1,100 **3.7**	—	4,200 **14.9**	29,000
36, - -	12,000 **23.9**	—	500 **1.1**	27,000 **51.1**	2,700 **5.**	—	3,700 **6.9**	3,000 **6.5**	—	2,500 **5.5**	53,000
48, - -	32,000 **21.8**	—	—	80,000 **50.**	7,500 **2.8**	—	25,000 **15.2**	—	—	16,000 **10.2**	160,000
60, - -	180,000 **21.1**	—	—	353,000 **44.4**	20,000 **2.2**	40,000 **5.6**	60,000 **7.8**	153,000 **18.9**	—	—	806,000
72, - -	400,000 **7.3**	—	80,000 **1.8**	5,360,000 **75.6**	—	200,000 **2.2**	720,000 **9.9**	780,000 **3.2**	—	—	6,940,000
84, - -	3,500,000 **11.4**	—	1,000,000 **3.5**	23,000,000 **77.5**	—	500,000 **1.9**	600,000 **2.1**	600,000 **2.3**	—	400,000 **1.3**	30,000,000
96, - -	21,000,000 **21.6**	—	—	68,000,000 **70.3**	—	300,000 **.4**	3,000,000 **3.**	2,300,000 **2.3**	—	2,500,000 **2.4**	97,000,000
120, - -	302,000,000 **46.8**	—	36,000,000 **5.5**	265,000,000 **41.1**	1,000,000 **.2**	1,500,000 **.2**	16,000,000 **2.5**	19,000,000 **2.9**	—	5,000,000 **.8**	646,000,000
144, - -	560,000,000 **60.3**	19,000,000 **2.**	70,000,000 **7.6**	233,000,000 **25.1**	—	3,000,000 **.4**	20,000,000 **2.2**	21,000,000 **2.3**	—	600,000 **.1**	927,000,000

TABLE II.

Bacterial development in milk kept at 20° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
6, - -	3,400 **6.2**	—	200 **.3**	24,000 **44.8**	9,200 **16.9**	—	1,000 **1.8**	1,600 **2.9**	—	15,000 **27.1**	54,000
12, - -	45,000 **17.**	—	1,500 **.5**	140,000 **54.1**	45,000 **17.4**	—	4,500 **1.7**	4,000 **1.5**	—	20,000 **7.8**	260,000
18, - -	169,000 **19.7**	—	15,000 **2.**	388,000 **44.8**	88,000 **8.1**	9,000 **1.3**	76,000 **11.1**	—	—	85,000 **13.0**	830,000
24,* - -	—	—	—	—	—	—	—	—	—	—	*
30, - -	83,000,000 **53.3**	—	4,000,000 **2.6**	59,000,000 **37.8**	1,470,000 **.9**	530,000 **.4**	4,200,000 **2.9**	—	—	3,000,000 **21.**	155,000,000
36, - -	550,000,000 **75.4**	16,000,000 **2.2**	25,000,000 **3.6**	107,000,000 **14.8**	1,300,000 **.2**	1,800,000 **.3**	7,100,000 **.9**	—	—	19,000,000 **2.6**	727,000,000
	2,128,000,000 **77.7**	390,000,000 **14.6**	33,000,000 **1.2**	164,000,000 **6.**	—	1,600,000 **.1**	9,600,000 **.4**	—	—	—	2,627,000,000

* Error in analysis.

TABLE 12.

Bacterial development in milk kept at 37° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
2, - -	5,400 **8.1**	8,500 **12.4**	500 **.8**	36,500 **53.1**	500 **.8**	67 **.1**	1,900 **2.7**	2,800 **4.2**	—	12,000 **17.8**	66,000
4, - -	16,000 **32.8**	—	1,200 **2.9**	8,500 **17.**	830 **1.3**	—	11,000 **20.4**	415 **1.**	—	12,000 **24.6**	50,000
6, - -	168,000 **32.6**	50,000 **8.2**	5,800 **1.**	93,000 **16.7**	68,000 **9.9**	830 **.3**	79,000 **13.3**	—	—	115,000 **18.**	580,000
8, - -	290,000 **12.6**	—	341,000 **14.7**	612,000 **22.9**	235,000 **10.**	—	734,000 **27.9**	—	—	300,000 **11.9**	2,500,000
10, - -	667,000 **5.4**	—	6,400,000 **51.4**	3,600,000 **24.6**	—	50,000 **.5**	1,900,000 **13.2**	—	—	500,000 **4.9**	13,000,000
12, - -	130,000 **.2**	—	64,000,000 **87.9**	4,470,000 **5.7**	—	—	3,700,000 **5.2**	800,000 **1.**	—	—	73,000,000
14, - -	1,000,000 **.3**	—	368,000,000 **98.4**	2,500,000 **.7**	—	—	1,800,000 **.5**	—	—	500,000 **.1**	373,000,000
16, - -	—	—	588,000,000 **97.9**	6,000,000 **1.**	—	—	5,100,000 **.9**	670,000 **.1**	—	340,000 **.1**	600,000,000

2. The lactic bacteria, Group I., began to increase a little later than Group IV., and rose to about 560,000,000 in 144 hours, at which time they constituted 60 per cent. of the whole.

3. Group III. began to increase about the same time, and continued to multiply till the close, increasing in percentage as well as in actual numbers.

4. The liquefying bacteria developed more than usual, and remained at about 30,000,000 during the last day or so.

5. The tables also show that at this temperature, as in other cases, there was a very general development of all species of bacteria present in the original milk, the only one to disappear totally being Group V. All others increased with considerable regularity through the whole experiment.

Milk kept at 20°.—1. The development of Group I. began very rapidly about the 20th hour, and rose with exceptional rapidity, until at 48 hours there were over 2,000,000,000 in each cubic centimeter; and if to these be added Group II., there were about 2,500,000,000 of lactic bacteria present before curdling took place.

2. Group III. developed slightly and was present at the end in considerable numbers, though in small percentage.

3. Group IV. continued to increase in numbers with decreasing percentage till curdling.

4. All other bacteria were largely excluded from the milk by the development of the lactic species.

5. The most striking phenomenon was the number of lactic bacteria that developed before curdling took place. The 10° milk contained 560,000,000 when it curdled, while the 20° milk contained five times as many. To what is due this difference in numbers present at the curdling period we are not yet convinced. It may be that in this particular case the large numbers of Group IV., which develop a slight alkaline reaction, may have counteracted the acid produced by Groups I., II., and III., and thus delayed the curdling.

Milk kept at 37°.—The results were almost a repetition of those of the last experiment, inasmuch as at the 16th hour, at the time of curdling, nearly 98 per cent. of the bacteria growth was confined to Group III., *B. aerogenes*, this group at the end constituting 98 per cent. of the whole. The other 2 per cent. consisted of a few of the neutral Group IV. and a few liquefiers. Here, as in experiment 3, the temperature of 37° stimulated particularly the development of *Bacterium aerogenes*, and this resulted in the practical disappearance of nearly all other species, even the very vigorous Group I. failing to develop in this sample of milk kept at 37°. The total number of bacteria present at curdling was far less than in the 20° sample.

EXPERIMENT NO. 5. MAY 19.

The conditions of this experiment were as in the last three, but the weather was warm and dry. The milk kept at 37° curdled in 18 hours, that kept at 20° curdled in about 45 hours (in the night), and that kept at 10° curdled in 312 hours, although no analysis was made later than 260 hours. The following tables, 13, 14, and 15, show the details of the analysis, and Plate 4 shows graphically the growth of the chief types.

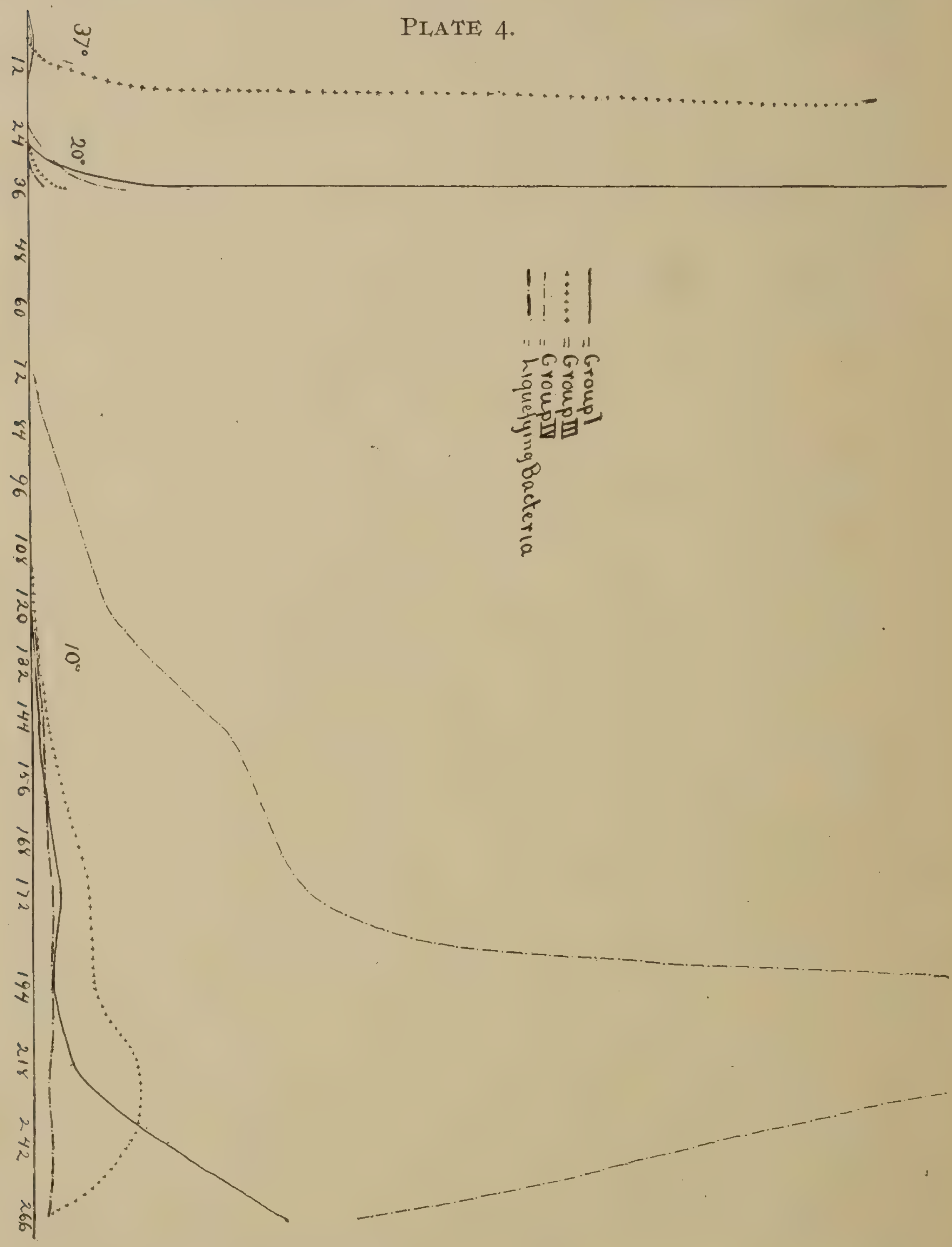
The results of this experiment were so similar to the last that only a brief mention of the essential points is necessary.

Milk kept at 10°.—All species of bacteria originally present developed uniformly, except Group IV., and all were present in a large percentage, even in the last test, made at the 266th hour. The chief growth was due to Group IV. and Group I. Group IV. developed to a phenomenally high number, the analysis at the 218th hour showing 3,500,000,000 per cubic centimeter, 94 per cent. of all the bacteria present at that time being of this type. In spite of these high numbers the milk did not curdle. After this period the lactic bacteria increased in numbers and percentage, while the neutral Group IV. decreased in both numbers and percentage. At the time of curdling these two groups were present in about equal numbers, shown graphically in Plate 4.

Group III. showed a constant development in numbers through the whole experiment until the last two analyses, when they noticeably declined in numbers.

Milk kept at 20°.—As in other cases, there was a rapid development of the Group I. after the first 12 hours. This type increased to over 1,000,000,000 in the 45 hours. The Group III. also developed during the whole experiment, and

PLATE 4.



was rather abundant at the end, although few in numbers compared with Group I. Group IV. increased in total numbers until the end, but decreased constantly in percentage. The other groups were detected in the last test, although few in numbers.

TABLE 13.—*Bacterial development in milk kept at 10° C.*

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
0,	1,750 **5.1**	—	100 **.3**	19,000 **54.9**	2,350 **6.8**	—	1,800 **5.2**	3,500 **10.0**	—	6,500 **17.7**	35,000
12,	2,600 **7.7**	133 **.4**	—	22,000 **64.4**	2,200 **6.5**	—	2,500 **7.3**	2,500 **7.4**	—	2,400 **6.3**	34,000
24,	1,025 **2.8**	—	250 **.8**	24,000 **66.0**	1,500 **4.2**	80 **.2**	4,600 **13.1**	600 **1.7**	—	3,800 **11.2**	36,000
38,	2,600 **5.9**	—	700 **1.**	29,000 **52.3**	1,400 **2.2**	900 **1.4**	3,900 **7.4**	5,700 **9.9**	—	12,000 **19.9**	56,000
50,	11,000 **5.2**	—	5,300 **2.5**	151,000 **69.3**	3,300 **1.2**	3,000 **1.3**	14,000 **6.4**	3,000 **1.8**	—	26,000 **12.3**	217,000
62,	71,000 **3.6**	—	11,000 **.6**	1,500,000 **78.1**	36,000 **1.8**	5,000 **.2**	48,000 **2.5**	137,000 **7.1**	—	114,000 **6.1**	1,900,000
74,	60,000 **.5**	—	50,000 **.4**	8,800,000 **80.4**	150,000 **1.4**	93,000 **1.0**	267,000 **2.5**	830,000 **7.4**	—	890,000 **6.4**	1,400,000
86,	280,000 **.7**	—	220,000 **.6**	30,000,000 **83.5**	330,000 **1.1**	370,000 **1.1**	1,000,000 **3.**	2,100,000 **5.9**	—	1,350,000 **4.1**	36,000,000
98,	800,000 **1.1**	—	4,600,000 **6.4**	57,000,000 **82.3**	133,000 **.2**	1,470,000 **2.**	2,000,000 **2.9**	3,100,000 **4.3**	—	533,000 **.8**	69,000,000
123,	2,000,000 **1.8**	—	8,000,000 **6.8**	94,000,000 **83.7**	200,000 **.1**	4,000,000 **3.4**	5,000,000 **4.2**	?	—	—	112,000,000
146,	11,000,000 **3.3**	—	30,000,000 **10.**	250,000,000 **77.6**	—	10,000,000 **3.0**	6,000,000 **1.8**	10,000,000 **3.0**	—	4,000,000 **1.3**	317,000,000
170,	46,000,000 **8.2**	—	88,000,000 **16.0**	344,000,000 **61.7**	—	18,000,000 **3.3**	7,500,000 **1.4**	26,000,000 **4.7**	—	27,000,000 **4.7**	556,000,000
194,	28,000,000 **1.5**	—	83,000,000 **4.6**	1,675,000,000 **92.3**	—	21,000,000 **1.2**	6,700,000 **.4**	—	—	—	1,814,000,000
218,	50,000,000 **1.3**	—	132,000,000 **3.7**	3,479,000,000 **94.2**	—	12,000,000 **.4**	14,000,000 **.4**	—	—	1,000,000 **?**	3,688,000,000
242,	176,000,000 **28.9**	1,000,000 **.1**	118,000,000 **19.3**	255,000,000 **41.9**	—	19,000,000 **3.1**	10,000,000 **1.5**	—	—	34,000,000 **5.2**	612,000,000
266,	309,000,000 **38.**	—	34,000,000 **3.7**	394,000,000 **49.7**	—	13,000,000 **1.7**	13,000,000 **1.6**	16,000,000 **1.8**	—	30,000,000 **3.5**	810,000,000

TABLE 14.

Bacterial development in milk kept at 20° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
6, - -	3,100 **8.7**	—	—	21,800 **60.8**	3,200 **8.8**	—	2,100 **5.8**	2,200 **6.1**	—	3,400 **9.8**	35,000
12, - -	12,000 **16.2**	—	500 **.3**	27,000 **40.4**	6,000 **4.6**	1,000 **.6**	17,000 **16.5**	1,000 **.6**	—	2,400 **20.8**	88,000
18, - -	80,000 **22.5**	—	21,000 **6.8**	65,000 **25.8**	25,000 **7.1**	—	40,000 **12.9**	2,000 **.7**	—	82,000 **24.2**	315,000
26, - -	1,300,000 **4.6**	—	633,000 **2.2**	20,000,000 **67.7**	660,000 **2.3**	200,000 **.7**	4,500,000 **15.5**	227,000 **.9**	—	1,765,000 **6.1**	29,000,000
32, - -	61,000,000 **42.0**	—	11,000,000 **8.1**	50,000,000 **36.9**	—	1,330,000 **1.0**	11,000,000 **7.9**	—	—	5,400,000 **4.1**	140,000,000
	1,084,000,000 **81.4**	51,000,000 **3.4**	55,000,000 **4.2**	120,000,000 **9.**	—	1,700,000 **.2**	18,000,000 **1.3**	6,000,000 **.5**	—	—	1,337,000,000

TABLE 15.

Bacterial development in milk kept at 37° C.

AGE IN HOURS.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
2, - -	300 **.5**	—	100 **.2**	17,300 **32.8**	1,100 **2.1**	300 **.6**	4,600 **8.7**	1,900 **3.6**	—	27,000 **51.5**	53.000
4, - -	821,000 **80.**	153 **14.7**	—	21,000 **2.0**	1,050 **.1**	—	27,700 **2.7**	—	—	5,400 **.5**	1,000,000
6, - -	4,200,000 **62.8**	1,200,000 **30.2**	13,000 **.2**	118,000 **2.3**	10,000 **.2**	833 **?**	245,000 **4.1**	8,000 **.2**	—	—	6,000,000
8, - -	260,000 **3.4**	7,000,000 **52.4**	1,400,000 **20.7**	985,000 **12.7**	25,000 **.3**	20,000 **.2**	690,000 **8.4**	—	—	310,000 **1.9**	11,000,000
10, - -	3,200,000 **9.8**	7,000,000 **14.5**	17,000,000 **60.6**	3,700,000 **11.6**	—	—	900,000 **2.6**	—	—	200,000 **.9**	32,000,000
12, - -	—	—	91,000,000 **96.4**	1,200,000 **1.4**	—	—	500,000 **.5**	—	—	1,800,000 **1.7**	94,000,000
14, - -	500,000 **?**	—	175,000,000 **99.9**	1,500,000 **.1**	—	—	—	—	—	—	177,000,000
16, - -	—	—	472,000,000 **100.**	—	—	—	—	—	—	—	472,000,000
18, - -	—	—	474,000,000 **100.**	1,000,000 **?**	—	—	—	—	—	500,000 **?**	474,000,000

Milk kept at 37°.—This sample showed the most interesting result of any of our experiments; for at 16 hours and 18 hours, the time of curdling, the only bacteria present were those of Group III., *B. aerogenes.* These developed to the extent of 470,000,000 per cubic centimeter, and all other species had disappeared except a very small number of Group IV., too small to be indicated in percentage.

Plate 4 shows in an exceptionally striking way the contrast between the growth of bacteria in the three samples.

EXPERIMENT NO. 6. JUNE 10.

A repetition of the other experiments, except that the milk was slightly fresher when first plated—about one hour after milking. The milk at 37° curdled in 11 hours, that kept at 20° in 40 hours, and that at 10° in 270 hours. The weather was warm and damp. The study of the milk at 20° and 10° showed nothing peculiar, but the 37° sample was very exceptional in curdling in 11 hours and in containing few bacteria. Tables 16, 17, and 18 show the details of analysis.

Milk kept at 10°.—The only points especially to be noticed are the following. There was a general growth of all species except Groups V. and VIII. Groups I. and IV. constituted 98 per cent. of all at the time of curdling, Group I. being about twice as abundant as Group IV., but Group IV. showed 1,200,000,000 per cubic centimeter. The total number of bacteria was very high, and, as a consequence, the last three tests are not very reliable.

Milk kept at 20°.—As usual, Group I. grew rapidly, and at 36 hours there were 1,870,000,000 per cubic centimeter. Group IV. developed also, not being so completely checked as usual. No other bacteria developed.

Milk kept at 37°.—This showed a very peculiar result. The milk curdled in 11 hours, but at that time contained *only 8,000,000 of bacteria*, only 5 per cent. of which were acid bacteria, Group III., and none of which belonged to Groups I. and II. Of the bacteria 63 per cent. were liquefiers, although these were only about 5,000,000 per cubic centimeter. The milk was certainly not curdled by lactic bacteria, and doubtless the rennet enzymes produced by the liquefiers curdled the milk. This is the only example we have ever had the opportunity to study where normal milk was curdled by liquefiers rather than by lactic bacteria.

TABLE 16.—*Bacterial development in milk kept at 10° C.*

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
0,	2,380 **2.8**	—	—	49,800 **58.6**	2,550 **3.**	1,530 **1.8**	10,700 **12.6**	2,450 **2.9**	—	15,700 **18.4**	85,000
12,	270 **.3**	—	—	59,000 **64.**	4,200 **4.5**	2,300 **2.5**	10,000 **11.0**	—	—	16,200 **17.7**	92,000
24,	1,000 **.3**	—	650 **.2**	308,000 **91.8**	1,000 **.3**	2,000 **.6**	20,000 **5.9**	—	—	3,000 **.9**	336,000
38,	2,350 **.1**	—	2,350 **.1**	2,160,000 **92.7**	2,350 **.1**	4,700 **.2**	150,000 **6.3**	—	—	12,000 **.5**	2,300,000
50,	6,800 **.1**	—	6,800 **.1**	6,500,000 **95.8**	17,600 **.2**	6,800 **.2**	238,000 **3.5**	—	—	6,800 **.1**	6,800,000
62,	12,000 **.1**	—	36,000 **.3**	11,000,000 **94.6**	—	24,000 **.2**	540,000 **4.5**	—	—	36,000 **.3**	12,000,000
74,	400,000 **1.4**	—	—	25,000,000 **86.9**	260,000 **.9**	58,000 **.2**	3,670,000 **9.9**	—	—	200,000 **.7**	29,000,000
86,	2,300,000 **4.5**	—	159,000 **.3**	43,000,000 **81.**	795,000 **1.5**	265,000 **.5**	6,000,000 **11.5**	—	—	371,000 **.7**	53,000,000
98,	9,600,000 **10.2**	—	—	75,000,000 **79.8**	1,100,000 **1.2**	376,000 **.4**	6,100,000 **6.5**	—	—	1,800,000 **1.9**	94,000,000
122,	60,000,000 **28.9**	—	3,300,000 **1.6**	123,000,000 **59.3**	6,200,000 **3.**	4,100,000 **2.**	7,300,000 **3.5**	—	—	3,500,000 **1.7**	208,000,000
147,	450,000,000 **59.2**	—	15,000,000 **2.**	263,000,000 **34.6**	—	12,000,000 **1.6**	20,000,000 **2.6**	—	—	—	760,000,000
171,	1,032,000,000 **63.3**	—	56,000,000 **2.9**	508,000,000 **31.8**	—	14,000,000 **.9**	14,000,000 **.9**	—	—	3,200,000 **.2**	1,600,000,000
195,	— **56.1**	—	— **1.7**	— **25.**	—	— **.4**	— **1.6**	—	—	— **15.2**	—
219,	— **65.5**	—	— **2.1**	— **31.5**	—	—	— **.9**	—	—	—	—
243,	2,029,000,000 **61.5**	—	49,000,000 **1.5**	1,200,000,000 **36.7**	—	3,300,000 **.1**	9,900,000 **.3**	—	—	66,000,000 **.2**	3,300,000,000

TABLE 17.

Bacterial development in milk kept at 20° C.

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
6,	900	—	—	236,000	18,000	1,200	39,000	—	—	4,800	300,000
	.3			78.8	5.9	.4	13.0			1.6	
12,*	—	—	—	—	—	—	—	—	—	—	—
18,	2,700,000	—	66,000	26,000,000	3,300,000	33,000	2,600,000	—	—	460,000	33,000,000
	8.2		.2	81.	1.0	.1	8.1			1.4	
25,	106,000,000	—	—	92,000,000	—	—	13,000,000	—	—	1,000,000	212,000,000
	50.1			43·3			6.1			.5	
30,	813,000,000	—	—	700,000,000	—	11,000,000	106,000,000	—	—	9,600,000	1,600,000,000
	50.8			42.5		.7	5.4			.6	
36,	1,870,000,000	—	—	284,000,000	—	—	43,000,000	—	—	4,400,000	2,200,000,000
	85.			12.9			1.9			·2	

* Dilution too low.

TABLE 18.

Bacterial development in milk kept at 37° C.

Age in Hours.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Miscellaneous and Undetermined.	Total.
2,	1,300 **1.8**	—	—	45,000 **62.2**	3,100 **4.3**	2,000 **2.7**	9,000 **12.3**	370 **.5**	—	12,000 **16.2**	73,000
4,	6,400 **1.8**	—	—	57,000 **16.2**	3,100 **.9**	9,200 **2.6**	265,000 **75.**	5,700 **1.6**	—	6,400 **1.9**	353,000
6,*	—	—	—	—	—	—	—	—	—	—	—
8,	—	—	44,000 **1.2**	806,000 **21.8**	29,600 **.8**	38,500 **10.4**	2,400,000 **64.9**	—	—	330,000 **.9**	3,600,000
10,	—	—	467,000 **5.7**	894,000 **10.9**	—	598,000 **7.3**	5,220,000 **63.7**	—	—	1,000,000 **12.4**	8,200,000

* Results unreliable. The milk then curdled, although it contained only few acid bacteria. The liquefiers, on the other hand, were abundant. The total numbers were very small.

EXPERIMENTS NOS. 7, 8, 9.

In the three following experiments the observations were extended in two directions. 1. The attempt was made to differentiate the species of bacteria more thoroughly upon the plates, and in the tables given below a larger number of different types have been separated from each other, and their numbers determined as far as possible. It will be evident from the tables, however, that these additional determinations of individual species do not affect the general problem, for the new species which are tabulated constitute only a very small proportion of the whole, while in all cases the types already referred to in the previous tables constitute the large majority. 2. The chief purpose of these three experiments was to extend the observations to milk kept at lower temperatures than those used in previous cases. To this end, one of the compartments in a cold storage plant was used for keeping one of the samples of milk. The temperature in this compartment was about 1° above freezing point, varying very slightly during the series of experiments, and probably never rising above 1°. We found that milk can be kept at this temperature for a long time, and that for many days it appears to be perfectly normal. It has already been shown, however, that bacteria will grow even at these low temperatures. Experiments on this subject have already been carried on by quite a number of investigators. Havemann (Ueber das Wachstum von Mikroorganismen bei Eiskranktemperatur. Inaug. Dis. Rostok, 1894) showed their growth at 0° in water; Glage (Zeit. f. Fleisch u. Milch hyg. XI. p. 131) found them to grow at this temperature in flesh. (Other references to similar observations are: Schmidt–Nielson, Cent. f. Bact. u. Par. IX. p. 145; Schmelk, Cent. f. Bact. u. Par. IV. p. 545; Conradi & Vogt, Zeit f. Hyg. XXX. p. 287; Fischer, Deut. Med. Woch, 1893; Muller, Arch. f. Hyg. XLVII. p. 127). The experiments hitherto performed have been almost wholly confined to a quantitative determination of bacteria, and have consisted in placing samples of culture material at a temperature of 0°, or a little above, and making quantitative determinations at various intervals. The result of this work in general has been to show that, even at a temperature of practically freezing, there is a growth of bacteria, which, though slow, may be considerable. The question of the *kinds* of bacteria that develop

at this temperature has, however, hardly been touched upon, although Schmidt and Neilson showed that five species which they had studied could grow at 0°. No observations have been made to determine what effect such low temperatures have in differentiating species in a medium containing at the outset many species of bacteria. It seemed desirable, therefore, to study this question in connection with the other experiments which have been carried on in our laboratory.

The method of performing the experiments was essentially the same as previously described. A sample of milk was brought to the laboratory, plates made from it immediately, and then the sample divided into three lots. One lot was placed at the temperature of 1° above freezing, a second at 10°, and a third at 20°. The three samples were then plated at varying intervals; the sample at 20° being plated every 6 hours, that at 10° every 24 hours, and that at 1°, for the first experiments, every 2 days, but later the tests were made at intervals of 3 or 4 days, and, in some experiments, not oftener than once a week. This change in the interval of analysis was made as a result of the study of the development of the bacteria in the early preliminary experiments. The plates were incubated and carefully studied, and all kinds of distinguishable colonies were determined. Samples of the colonies were isolated and subsequently carried through a series of cultures, for the determination of the characteristics of each species in question. The results of these determinations were to show that in most cases the species were those well known and already described, although a few of them appeared to be different. We found, in some of the experiments, that the species of bacteria which developed most abundantly at low temperatures were not those previously included in our lists. The most interesting of these was No. 259 of our list, which, as will be shown below, was very persistent even at low temperatures. In the tabulation given below it was necessary to change the method of arranging the figures, owing to the large number of species to be included.

EXPERIMENT NO. 7. OCTOBER 10.

The three samples of milk were treated as above described. The sample placed at 20° curdled in about 48 hours, and was strongly acid. There was a large amount of gas present in the

TABLE 19.—*Bacterial development in milk kept at 10° C.*

SPECIES OF BACTERIUM.(a)	0 Hours.	12 Hours.	24 Hours.	36 Hours.	48 Hours.	72 Hours.	96 Hours.	120 Hours.	148 Hours.	172 Hours.
Group I., 206,	825 3.6	500 1.9	940 3.3	1,530 5.3	4,000 7.3	20,000 .8	—	375,000 0.3	8,700,000 1.8	96,000,000 12.2
Group III., 208,	—	300 1.1	—	470 2.	2,500 5.	80,000 2.2	400,000 1.3	2,900,000 1.7	21,000,000 4.8	56,000,000 7.1
Group IV., 233 and 234,	17,175 70.2	15,300 59.7	16,590 60.6	15,470 59.0	32,830 54.	1,570,000 47.3	19,000,000 60.	98,000,000 64.4	263,000,000 62.5	276,000,000 34.7
Group V., Sarcina,	1,275 4.8	1,800 7.0	1,880 6.7	—	—	—	—	750,000 5.	—	—
Group VI., 237,	300 1.	400 1.6	—	3,270 12.9	5,000 9.	660,000 21.9	4,900,000 18.5	22,000,000 15.4	41,000,000 10.3	70,000,000 8.7
Group VII., 238,	2,325 10.	4.000 15.5	4,170 15.3	2,330 8.4	8,200 12.9	760,000 23.6	5,900,000 19.3	18,000,000 12.2	20,000,000 4.7	36,000,000 4.5
Group VIII., 240,	525 2.	350 1.4	790 2.8	1,670 6.2	3,300 5.5	—	—	—	—	—
198,	188 .7	—	—	—	—	—	—	—	—	—
Pink Yeast,	75 .3	50 .2	—	—	—	—	—	—	—	—
225,	75 .4	50 .2	145 .5	470 2.	—	—	400,000 .9	—	—	—
85,	37 .2	—	—	—	—	—	—	—	—	—
Acid liquefiers,	412 1.4	900 3.6	840 3.	100 .4	500 9.	—	—	—	—	—
113c,	113 .4	350 1.4	793 2.9	—	—	—	—	—	—	—
Undetermined and miscellaneous,	1,425 5.0	1,650 6.4	1,440 4.5	870 4.2	3,200 5.4	147,000 4.2	—	8,300,000 5.5	b65,000,000 15.9	b262,000,000 32.8
Total,	24,750	25,650	27,690	28,000	60,000	3,240,000	30,000,000	150,000,000	419,000,000	796,000,000

(a) The numbers in the first column refer to the number of the species in our list, to be published later.
(b) Probably all belong to Groups I. and IV., which are not differentiated on these plates because of the abundance of liquefiers.
(c) Includes three distinguishable varieties.

TABLE 20.—*Bacterial development in milk kept at 20° C.*

SPECIES OF BACTERIUM.	6 Hours.	12 Hours.	18 Hours.	24 Hours.	30 Hours.	36 Hours.
Group I., 206,	500 **1.9**	10,500 **6.2**	20,000 **.7**	633,000 **1.4**	34,000,000 **19.1**	49,000,000 **21.6**
Group III., 208,	300 **1.**	11,000 **6.4**	228,000 **7.5**	3,567,000 **8.3**	23,000,000 **13.3**	58,000,000 **28.4**
Group IV., 194, 233, 234,	15,400 **58.4**	83,000 **47.9**	1,890,000 **62.2**	32,000,000 **74.**	875,000 **.5**	76,000,000 **37.3**
Group V., Sarcina,	3,100 **11.7**	12,000 **6.8**	133,000 **4.3**	567,000 **1.3**	99,000,000 **56.7**	—
Group VI., 237,	100 **.4**	7,000 **3.9**	136,000 **4.5**	1,060,000 **2.5**	5,600,000 **3.2**	4,000,000 **2.2**
Group VII., 238,	3,750 **13.8**	18,000 **10.5**	306,000 **9.8**	1,967,000 **4.6**	7,000,000 **4.**	830,000 **.4**
Group VIII., 240,	550 **2.2**	—	53,000 **1.7**	667,000 **1.5**	—	6,000,000 **2.9**
Pink Yeast,	150 **.6**	500 **.3**	—	—	—	1,300,000 **.5**
225,	500 **2.1**	10,000 **6.**	17,000 **.4**	—	1,400,000 **8.**	1,900,000 **1.0**
113,*	700 **2.4**	8,000 **4.8**	24,000 **.7**	—	—	—
Undetermined and miscellaneous,	1,550 **5.4**	12,500 **7.2**	236,000 **8.2**	3,000,000 **6.4**	4,200,000 **24.**	12,000,000 **5.7**
Total,	27,000	178,000	3,040,000	42,000,000	175,000,000	208,000,000

*Includes three distinguishable varieties.

TABLE 21.

Bacterial development in milk kept at 1° C.

Species of Bacterium.	48 Hours.	96 Hours.	144 Hours.
Group I., 206,	1,000 5.	720 4.1	380 2.2
Group III., 208,	20 .1	40 .3	140 .9
Group IV., 245,	11,800 59.9	9,680 55.5	8,920 56.6
Group V., Sarcina,	1,140 5.9	1,040 6.0	560 3.3
Group VI., 237,	400 2.1	20 .1	2,260 14.
Group VII., 238,	3,160 16.3	3,320 18.3	2,300 14.2
Group VIII., 40,	240 1.7	780 4.6	460 2.9
Pink Yeast,	80 .4	80 .4	—
225,	—	240 1.1	—
85,	—	40 .2	—
113,	720 3.6	1,120 6.3	220 1.4
Undetermined and miscellaneous,	1,080 5.	560 3.1	760 4.5
Total,	19,000	18,000	16,000

curd, its presence being explained by the large number of the gas forming group, as shown in Table 19, on page 70. The sample placed at 10° curdled in about 190 hours into a soft smooth curd. The sample placed at 1° was, by a mistake, removed from the cold storage after three tests were made from it, and, therefore, we have, in the following table, only three sets of observations, the last one being at the end of the 6th day. This period was too short to give any indication as to the development of bacteria in milk at 1°, but is given with the tables for the sake of completeness. The details of experiments and the following points of significance are shown in tables 19, 20, and 21.

Milk kept at 10°.—During the period of the experiment all species of bacteria which were present originally in the milk in very small proportions only (1 or 2 per cent. of the whole)

disappeared as time elapsed. This shows, of course, that these types of bacteria can be of little or no significance in the phenomena that occur, and can have had practically no influence upon the milk.

The species of bacteria which continued to develop during the whole of the experiment were Groups I., III., IV., VI., and VII., all of which we found in earlier experiments. The neutral bacteria, Group IV., developed abundantly; the acid Groups I. and III. and the liquefying bacteria, Groups VI. and VII., all developed extensively.

In the last experiments also there was a large number of bacteria whose species could not be determined. There is no question that these practically all belonged to Groups I. and IV., but at the time when the plates were counted it was impossible to differentiate them definitely because of the large numbers of liquefiers present.

Perhaps the most striking feature of this experiment was the development of the liquefying bacteria, which, during the entire series of tests, not only constantly increased in numbers, but remained in a constantly high percentage, and, even at the end, comprised 13 per cent. of all the bacteria present. Recognizing that the liquefying bacteria are likely to produce putrefactive products, it is, of course, significant to find that these bacteria remained so numerous in this sample of milk, which had been preserved at the temperature of 10°.

Milk kept at 20°.—It will be seen that this experiment differs somewhat from those described above, in that the milk which was kept at 20° did not show the usual development of the ordinary lactic bacteria, Group I. At the time of curdling, this group of bacteria comprised only about 21 per cent. of the whole, while Group III. comprised 37 per cent. of the whole. In this respect, then, the result was somewhat unique, and suggested that there are some conditions other than those of simple temperature which determine whether or not the bacteria of the first group shall get the upper hand of the other species.

It will also be noticed that practically all of the species found in the first sample of milk continued to develop during the entire period, and were present in about equal quantities at the end.

6

This is probably explained by the fact of the great development of Group IV. instead of the acid forming Group I., since the development of acid commonly checks the growth of bacteria. The miscellaneous species developed in this case, unhindered by such acidity. It will be seen, however, that the liquefying bacteria, Groups VI. and VII., were reduced very greatly in percentage, although they actually increased in numbers for 36 hours.

The sample of Milk kept at 1°, as already stated, was unfortunately removed from the cold storage after three tests were made. These three tests, as given in the tables, only show that during 148 hours, at 1°, there was practically no change in the bacteria in the milk, the numbers remaining nearly constant, and the percentage of each test remaining about the same. One or two of the species originally present in small numbers were not found in the third test, and had very likely disappeared.

EXPERIMENT NO. 8. DECEMBER 4.

In this experiment the conditions were an exact repetition of those of the last experiment. The milk kept at 20° curdled in 48 hours, just at the time of making the last test. Milk kept at 10° did not curdle, but became somewhat thick after 240 hours. The tests were carried on for some time after this, and the last test was made at 408 hours, when the milk was thick but not curdled. The milk kept at 1° was tested at varying intervals, as shown by the table, for 42 days. At the end of 42 days it was not curdled, although it was somewhat thick. The experiment showed a number of peculiarities which may best be explained in connection with the tables which contain the data.

The most peculiar and interesting feature of this experiment was the appearance in all samples of a species of bacterium which had not been found before, and which apparently modified the results in a very extraordinary way. This species belonged to Group IV., but when the detailed characteristics were studied it was found to be a species not hitherto described, and it was tabulated in our list as No. 249. It was an organism that grows well at low temperatures, but does not grow at high temperatures. It produced no acid reaction, but, on the other hand,

TABLE 22.

Bacterial development in milk kept at 1° C.

	0 Hours.	72 Hours.	6 Days.	11 Days.*	14 Days.*	19 Days.	21 Days.	25 Days.	27 Days.	36 Days.	42 Days.
Group I., 206, - -	2,075 **3.0**	1,760 **9.0**	876 **7.3**	—	—	—	—	—	—	—	—
Group III., 208, -	—	—	33 **.2**	—	—	2,575,000 **3.1**	68,000,000 **10.4**	234,000,000 **28.6**	359,000,000 **21.3**	405,000,000 **28.9**	274,000,000 **40.7**
Group IV., 194, 249, -	36,000 **52.8**	9,960 **49.9**	7,000 **55.4**	—	—	122,000,000 **79.1**	403,000,000 **62.1**	325,000,000 **39.2**	928,000,000 **54.9**	750,000,000 **53.6**	325,000,000 **47.5**
Group V., Sarcina, -	1,400 **1.8**	2,360 **11.2**	234 **2.**	—	—	—	—	—	—	—	—
Group VI., - -	36 **.1**	150 **.8**	33 **.2**	—	—	—	—	—	—	—	—
Group VII., - -	3,800 **5.7**	1,607 **8.0**	1,033 **8.6**	—	—	7,480,000 **4.9**	46,000,000 **7.1**	139,000,000 **17.1**	258,000,000 **15.1**	143,000,000 **10.**	13,000,000 **1.9**
Group VIII., 222, -	3,700 **5.4**	—	— **.9**	—	—	18,000,000 **12.9**	139,000,000 **20.4**	128,000,000 **15.1**	149,000,000 **8.7**	100,000,000 **7.5**	67,000,000 **9.9**
225, - - - -	800 **1.2**	100 **.5**	400 **3.6**	—	—	—	—	—	—	—	—
246, - - - -	13,400 **20.**	130 **.6**	100 **.6**	—	—	—	—	—	—	—	—
241, - - - -	—	100 **.6**	100	—	—	—	—	—	—	—	—
113,? - - - -	670 **10.**	100 **.6**	2,760	—	—	—	—	—	—	—	—
Undetermined and miscellaneous, - -	—	2,600 **18.8**	— **31.2**	—	—	—	—	—	—	—	—
Total, - - -	66,000	19,000	12,500	—	—	150,000,000	650,000,000	826,000,000	1,694,000,000	1,398,000,000	679,000,000

*Dilution too low.

TABLE 23.—*Bacterial development in milk kept at 10° C.*

	24 Hours.	48 Hours.*	72 Hours.	96 Hours.	120 Hours.†	336 Hours.	408 Hours.
Group I., 206,	190 .1	—	147,000 .4	—	—	248,000,000 66.4	96,000,000 51.4
Group III., 208,	—	—	287,000 1.2	3,000,000 .5	—	1,000,000 .4	—
Group IV., 194 and 249,	194,000 56.2	—	30,000,000 81.7	54,000,000 10.9	—	84,000,000 24.9	73,000,000 41.5
Group V., Sarcina,	542 .1	—	—	—	—	—	—
Group VI., 243,	148 ?	—	—	—	—	—	—
Group VII., 244,	3,063 10.	—	2,410,000 9.2	16,000,000 2.9	—	25,000,000 7.1	12,000,000 7.1
Group VIII., 222,	—	—	1,147,000 7.3	—	—	—	—
225,	200 .3	—	—	—	—	—	—
246,	137,000 40.2	—	13,000 .1	—	—	—	—
Yeast,	7,400 2.1	—	13,000 .1	—	—	—	—
Undetermined,	—	—	—	521,000,000 85.7	—	3,000,000 1.2	—
Total,	343,000	—	34,000,000	594,000,000	—	361,000,000	181,000,000

* Contaminated.

† From this point the numbers increased so rapidly that differentiation of the species was impossible. Plates were made every 24 hours, and the numbers rose to 200,000,000,000 per cubic centimeter in 312 hours, after which they dropped again as shown in the two following columns.

TABLE 24.

Bacterial development in milk kept at 20° C.

	6 Hours.	12 Hours.	18 Hours.	24 Hours.	30 Hours.	36 Hours.	48 Hours.
Group I., 206,	1,100 1.2	306,000 9.	198,000 2.4	3,000,000 1.	54,000,000 33.4	765,000,000 28.9	1,704,000,000 27.7
Group III., 208,	—	5,000 .1	12,000 .2	500,000 .3	7,000,000 4.4	14,000,000 .5	6,000,000 .1
Group IV., 194, 249,	75,000 78.9	3,265,000 72.6	11,000,000 80.6	244,000,000 94.8	77,000,000 47.1	1,915,000,000 70.0	4,599,000,000 72.
Group V., Sarcina,	2,300 2.1	271,000 4.6	35,000 .4	—	—	—	—
Group VI.,	—	—	20,000 .2	100,000 ?	2,100,000 1.4	5,000,000 .2	—
Group VII.,	4,100 5.	210,000 3.9	811,000 8.0	2,100,000 .9	7,200,000 4.5	9,000,000 .4	12,000,000 .2
Group VIII., 222,	—	—	—	—	—	—	—
225,	550 1.6	90,000 1.4	111,000 1.1	700,000 ?	—	—	—
246,	8,900 9.5	465,000 7.5	656,000 4.8	3,000,000 1.3	—	—	—
Yeast,	1,600 1.6	51,000 .9	300,000 2.3	5,000,000 1.7	—	—	—
Miscellaneous,	100 .1	2,000 ?	—	—	15,000,000 9.2	—	—
Total,	94,000	4,600,000	13,000,000	259,000,000	—	2,708,000,000	6,321,000,000

it rendered the milk alkaline, and it developed in most extraordinary numbers in all three samples of milk, particularly in those kept at low temperatures. The numbers increased in the 10° milk to 200,000,000,000 per cubic centimeter, a number never before found by us in any sample of milk studied. The enormous development of this species of bacteria rendered the results quite different from those of other experiments, and made worthless quite a large number of the plates kept at 10°. The dilutions which we adopted were those which experience has shown us to be proper for an ordinary development, but were entirely too low for samples of milk where this particular species developed in such very great numbers.

Milk kept at 1°.—1. Tests were made at intervals of 3 or 4 days for a period of 42 days, as shown in Table 22. The most noticeable feature was the development of the Group IV., which contained, at first, two species, Nos. 194 and 249. The No. 194 appeared to be abundant at the start, but after a while it was replaced by No. 249, and, apparently, at the close of the test No. 249 was the only one remaining alive in the milk. It was impossible to differentiate the two in our counting of the colonies on the plates, hence we cannot say positively that the 194 had completely disappeared; but most of the colonies present at the end were of species 249.

2. For 6 days there was no increase in numbers, and indeed, the number present on the 6th day was less than at the start. After the 6th day the numbers of the Group IV. began to increase rapidly, so rapidly and unexpectedly that the next two tests made were not diluted sufficiently to enable us to determine with any accuracy either numbers or species of bacteria. They are, therefore, omittted from the table.

3. The milk did not curdle even after the 42nd day, although it became somewhat thick and acid.

4. The number of bacteria became very high, although not so high as in the same milk kept at 10°. In 27 days there were about 1,700,000,000 bacteria per cubic centimeter, after which they were reduced in numbers. In 36 days the number of acid bacteria was 400,000,000, enough to have curdled the milk under ordinary conditions; but the enormous development of the

Group IV., as well as the large number of liquefying bacteria, which produced an alkaline reaction, neutralized the acid developed to such an extent that no curdling took place. At the close of the experiment the acid bacteria had come to be nearly as abundant as those of Group IV., but even at this time no curdling took place.

5. The liquefying bacteria continued to develop constantly during the whole experiment, and were present in large numbers at the end—about 10 per cent.

Milk kept at 10°.—1. Here the species No. 249, above referred to, produced a modification even greater than at 1°. Table 23 shows that Group IV. contained two species, No. 194, which was abundant in the early experiments, and No. 249, which was abundant in the later experiments. Inasmuch, however, as these two species were not readily distinguishable on the plates, it was impossible to separate their colonies and determine their proportions in successive tests; nor was it possible to state when No. 249 began to develop at the expense of No. 194.

2. After the 96th hour the species No. 249 began to develop with a rapidity never before seen by us in any experiment, so that the numbers grew phenomenally high. The plates made from this time up to 336 hours showed such very high numbers that differentiation of species was absolutely impossible, and though an attempt was made to procure such differentiation, the results are too unreliable for tabulation. The numbers of bacteria in the plates indicated that the milk contained, at about 300 hours, as many as 200,000,000,000 per cubic centimeter, the number having risen regularly, in successive hours, to this point. After this time the number dropped back again. The final tests, made at 336 and 408 hours, were once more within the reach of our experimental methods; a differentiation of the species was possible, and it is given in the last two columns of the table. These two columns show that, at this time, 24 per cent. and 41 per cent. respectively of the bacteria were of the species No. 249, but that the bacteria of Group I. had now become more abundant than Group IV. The liquefiers also became quite abundant at the end.

The explanation of this unusual series of tests seems to be in the peculiarities of this No. 249, which is capable of growing prodigiously in milk at low temperatures, if unhindered by other species. The lactic bacteria develop so slowly at 10° that it was not until after 300 hours that the amount of acid developed became sufficient to check the exceptional development of No. 249; but from this time on they were overpowered by the developing acid, and dropped down in the end to a comparatively small number.

Milk kept at 20°.—At this temperature the Group IV. constantly increased in numbers until, at 48 hours, there were over 4,500,000,000 per cubic centimeter. At the same time there were 1,700,000,000 of the lactic Group I. and small numbers of other species. This experiment shows, therefore, that the 20° temperature stimulates the development of the lactic bacteria of Group I., as it has in all other cases, but that the milk does not curdle so quickly as usual. In most cases the milk curdles when the number of bacteria is from 500,000,000 to 1,000,000,000 per cubic centimeter, but in this experiment it did not curdle until it reached nearly 2,000,000,000. The explanation of this fact seems to be due to the large numbers of Group IV., which neutralized to a certain extent the acid developed by Group I. It will also be noticed that, with the exception of a small percentage of liquefiers, all other bacteria disappeared from the milk, except the two groups of acids and the neutral Group IV. In other words, this experiment resembles those previously described at 20°, with the exception of the enormous development of this No. 249, which modifies the results.

The general result of this experiment may be stated, briefly as follows: This sample of milk apparently contained a species of bacterium which was particularly adapted to grow at low temperatures. The result was that the sample of milk kept at 10° and at 1° became filled with bacteria to an extent not found in any other sample of milk ever studied in our laboratory. The development of this species seemed for a time to check the development of all others; but in the end the lactic bacteria gradually overcame this species, No. 249, as well as all others, and in the final tests the acid organisms were about as

abundant as in previous tests. The whole experiment is quite anomalous, and suggests a condition of things that may, perhaps, explain cases of ice cream poisoning. Experiments are being carried on at the present time to determine whether the species 249 (as well as others that grow at 10°) produces any toxic products when growing in milk at low temperatures. The report upon these experiments will appear later.

This experiment of Dec. 4 was a very long one, requiring two months or more for its completion, and involving the making and the studying of several hundreds of cultures.

EXPERIMENT NO. 9. JANUARY 29.

This experiment was a repetition of the last. The sample of milk at 20° curdled in about 40 hours (in the night), showing no signs of gas. The sample at 10° curdled in about 180 hours, and began to digest rapidly. The sample at 1° was tested at intervals for 40 days. It never curdled, although it became somewhat acid, and it thickened.

The details of the analyses are given in the Tables 25, 26, and 27, and the growth of the chief types of bacteria are shown graphically in Plate 5. It should be remarked that all of the plates made in the analyses in this experiment proved satisfactory except a single series of the 1° sample, and the whole represents one of the most satisfactory series of analyses that we have made.

Milk kept at 1°—1. This temperature held the growth of bacteria in check for about 8 days, after which all types except the Groups V. and No. 225 began to multiply. The development was slow, however, *requiring 33 days to equal the number found in the 20° sample in 36 hours.*

2. All of the chief types of bacteria developed abundantly, and were present in high percentage at the close of the experiment. The contrast between this result and that obtained at 20° is very strikingly shown by Plate 5.

3. The lactic bacteria of Group I. developed constantly and became very abundant after 30 days, but later they declined in numbers.

TABLE 25.

Bacterial development in milk kept at 1° C.

	0 Hours.	96 Hours.	8 Days.*	16 Days.	24 Days.	33 Days.	40 Days.
Group I., 206,	1,750 6.9	1,070 6.9	—	1,500,000 .4	158,000,000 19.2	734,000,000 43.4	389,000,000 55.1
Group III., 208,	100 .5	130 .9	—	1,600,000 .4	55,000,000 6.7	100,000,000 5.9	20,000,000 2.7
Group IV., 198 and 249,	10,500 42.9	10,400 65.4	—	186,000,000 53.4	352,000,000 42.9	307,000,000 18.6	57,000,000 7.9
Group V., Sarcina,	1,300 5.3	130 .9	—	—	—	—	—
Group VI., 261,	50 .9	200 1.0	—	—	2,000,000 .2	—	—
Group VII.,	5,400 22.1	2,760 17.	—	135,000,000 39.3	255,000,000 30.8	357,000,000 19.6	93,000,000 12.6
Group VIII., 249,	2,750 10.4	1,200 7.4	—	14,000,000 6.5	—	254,000,000 14.1	122,000,000 16.6
225,	550 2.1	—	—	—	—	—	—
Miscellaneous,	2,000 8.9	70 .5	—	—	1,500,000 .2	—	53,000,000 6.1
Total,	24,300	16,000	—	346,000,000	856,000,000	1,755,000,000	730,000,000

* Dilution too low.

TABLE 26.

Bacterial development in milk kept at 10° C.

	24 Hours.	48 Hours.	72 Hours.	96 Hours.	120 Hours.	144 Hours.	168 Hours.
Group I., 206,	100 **.8**	—	—	1,100,000 **.9**	7,400,000 **2.6**	77,000,000 **13.4**	119,000,000 **13.4**
Group III., 208,	100 **.8**	4,600 **.4**	200,000 **.4**	1,100,000 **.9**	11,000,000 **4.2**	34,000,000 **5.8**	44,000,000 **4.9**
Group IV., 250, 249,	10,300 **75.8**	795,000 **68.5**	41,000,000 **80.9**	86,000,000 **64.3**	176,000,000 **62.5**	266,000,000 **46.3**	304,000,000 **34.9**
Group V., Sarcina,	1,100 **6.8**	—	—	—	—	—	—
Group VI.,	—	74,000 **6.4**	220,000 **.4**	—	—	—	—
Group VII.,	650 **5.**	255,000 **22.2**	8,100,000 **15.6**	32,000,000 **23.7**	52,000,000 **18.3**	62,000,000 **10.7**	185,000,000 **21.0**
Group VIII.,	924 **6.4**	26,000 **2.2**	1,300,000 **2.6**	11,000,000 **8.3**	31,000,000 **11.1**	51,000,000 **8.9**	47,000,000 **5.4**
Acid liquefiers,	93 **.7**	3,400 **.3**	100,000 **.2**	2,500,000 **1.9**	3,700,000 **1.3**	18,000,000 **3.1**	10,000,000 **1.4**
Miscellaneous,	350 **3.7**	—	—	—	—	67,000,000 **11.8**	166,000,000 **19.0**
Total,	13,500	1,160,000	51,000,000	133,000,000	281,000,000	575,000,000	875,000,000

TABLE 27.

Bacterial development in milk kept at 20° C.

	6 Hours.	12 Hours.	24 Hours.	30 Hours.	36 Hours.
Group I., 206, - -	2,000	47,000	14,000,000	278,000,000	1,060,000,000
	4.	12.5	24.8	66.3	73.6
Group III., 208, -	—	2,600	3,000,000	19,000,000	31,000,000
		.7	5.3	4.2	2.5
Group IV., 198, 249,	28,000	166,000	22,000,000	76,000,000	90,000,000
	57.6	44.5	40.	18.6	6.9
Group V., Sarcina, -	11,000	25,000	—	—	800,000
	22.3	6.8			
Group VI., - -	5,000	20,000	1,000,000	4,700,000	10,000,000
	11.1	5.3	2.1	1.2	.8
Group VII., - -	500	31,000	3,000,000	14,000,000	18,000,000
	1.1	8.4	5.0	2.5	1.4
Group VIII., - -	400	15,000	2,000,000	4,700,000	—
	.8	4.1	3.9	1.2	
Acid liquefiers, - -	400	—	3,000,000	7,000,000	5,700,000
	.8		5.0	1.6	.4
	1,400	66,000	7,000,000	20,000,000	167,000,000
	3.3	17.7	13.9	4.4	14.4
Total, - - -	48,000	370,000	54,000,000	420,000,000	1,323,000,000

4. The particularly high number of liquefiers—see Plate 5—is especially worthy of notice, these numbers and high percentage being very unusual, and, indeed, not found in any other of our experiments.

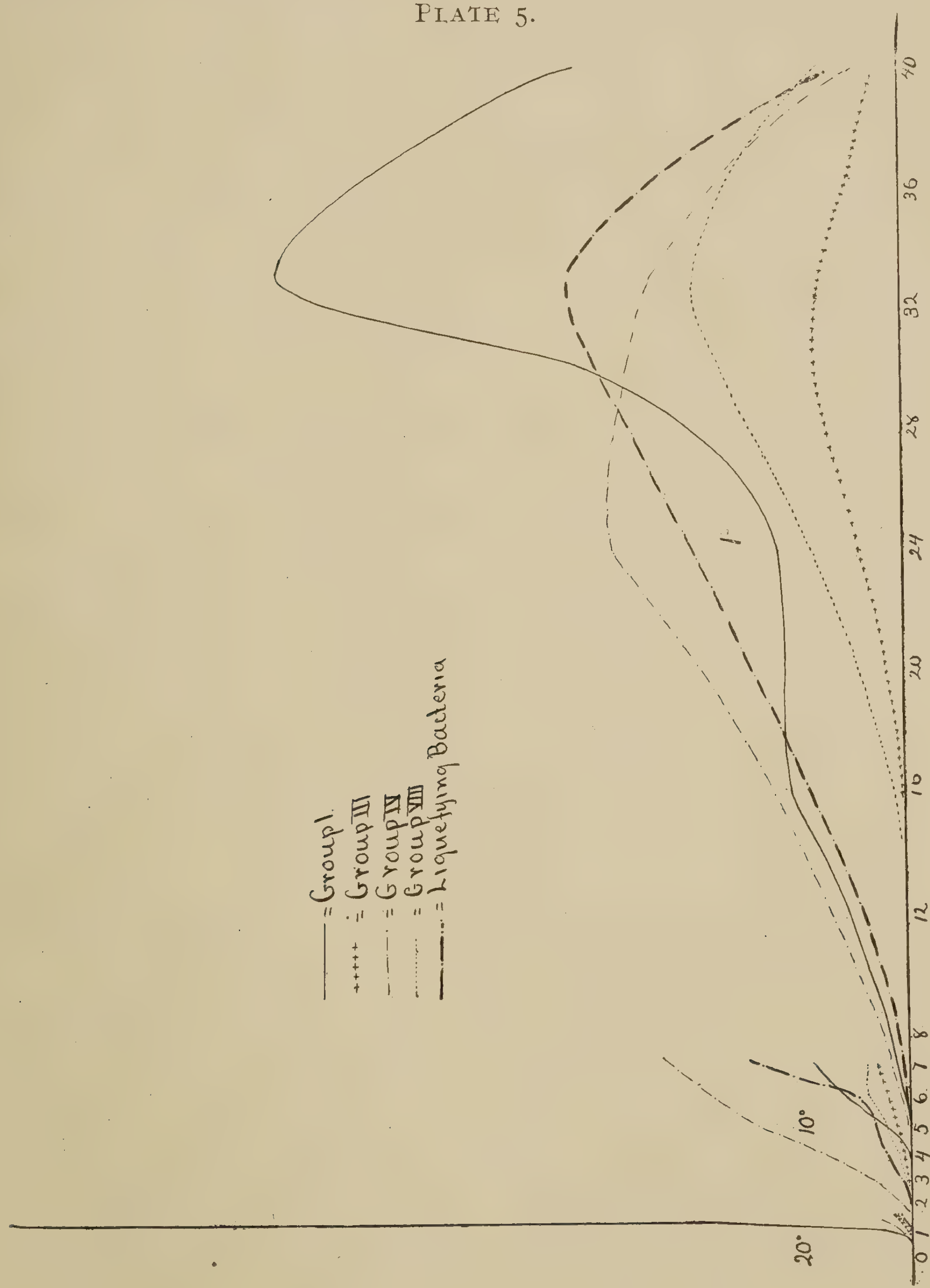
5. The decline of bacteria after 36 hours is in accordance with other experiments, and, as shown in Plate 5, it effects all species.

Milk kept at 10°—1. The effect of this temperature was almost identical with that of 1°, except that the growth of the bacteria took place more quickly, being indeed, finished by the time the growth of bacteria in the cooler sample began. See Plate 5. Here, too, all types of bacteria developed abundantly, although the neutral Group IV. surpassed the latic Group I.

2. The number of lactic bacteria present at the time of curdling is small, but the number of liquefiers is exceptionally high. Moreover, as above mentioned, the milk began to digest quickly after curdling. Hence, the curdling of the milk in

this sample was the result of enzym action rather than a simple acid curdling. It is suggestive to note that the number of acid bacteria and liquefying bacteria in this curdled sample was far less than in the 1° sample at 32 days, although the latter did not curdle, a fact very likely explained by the weak action of enzyms at low temperatures.

PLATE 5.



3. The representative of Group IV. that was so abundant in the sample after 6 days was No. 249, the same species that developed at 1°.

Milk kept at 20°.—This followed the general course of milk at this temperature. The lactic Group I. developed very rapidly, and largely checked the growth of the other types. The liquefiers proved themselves rather more persistent than usual in milk at this temperature, and were quite evident at the time of curdling. Their percentage, however, was small, about 2 per cent., and they clearly had no appreciable action on the milk.

GENERAL SUMMARY.

From the experiments here recorded, together with those published in the Annual Report of 1902–3, the following general summary may be given of the effect of different temperatures upon the development of the types of bacteria in ordinary market milk.

1. The effect of variations in temperature upon the development of the different species of bacteria in milk is not always the same under apparently identical conditions. Such variations are to be expected when we bear in mind that different samples of milk vary so widely in their bacterial content at the outset. The presence of an especially persistent species in any lot of milk may, at any time, be expected to interfere with the normal course of events and to produce unusual results. But in spite of these variations there appears to be clearly discernible a normal development of bacteria associated with different temperatures.

2. There is, in all cases, a certain period at the beginning when there is no increase in total numbers of bacteria. During this period some species are multiplying, while others are apparently dying. The length of this period depends upon temperature. At 37°C. it is very short, while at 1°C. it may last from 6 to 8 days, since, at this temperature, milk may, in 6 days, actually contain fewer bacteria than when fresh.

3. After this preliminary period there always follows a multiplication of bacteria; but the types that develop differ so markedly that samples of the same milk kept at different temperatures are, at later periods, very different in their bacterial content, even though they contain the same number of bacteria.

4. The development of the ordinary lactic species, *Bact. lactis acidi*, in practically all cases checks the growth of other species of bacteria, and finally kills them, since the bacteria regularly decrease in actual numbers after the lactic bacteria have become very abundant. The development of lactic bacteria thus serves as a protection both to the milk and the person drinking it, since it prevents the growth of other bacteria. This effect is probably due to the production of lactic acid, and is not noticeable in milk only a few hours old. The presence of large numbers of lactic bacteria in milk is not an indication that the milk is unwholesome.

5. In practically all samples of milk kept at 20°C. the multiplication of the *Bact. lactis acidi* begins quickly, and progresses with great rapidity. They grow so rapidly that they produce acid enough to curdle the milk in about 40 hours, the growth of other species being held in check. Milk, when curdled at this temperature, shows a smooth acid curd, with no gas bubbles, such as a butter maker or a cheese maker likes to see, and contains commonly over 90 per cent. of *Bact. lactis acidi*. This is the temperature favorable to ordinary dairy processes.

6. A totally different result appears in milk kept at 37°C. The results are somewhat more variable than at 20°. Occasionally the *Bact. lactis acidi* grows vigorously at this temperature, but the common effect is that a different type of lactic bacteria develops. The type favored by this temperature is the species *B. lactis aerogenes*. It is a gas producer, and produces a different type of acid from that produced by *B. acidi lactici*. (Kozai. Zeit. f. Hyg., XXXVIII., 1901, and Utz. Cent. f. Bact., II., XI. p. 600, 1904). It forms a curd full of gas bubbles, and is an enemy of the butter and cheese maker. If *B. coli communis* is in the milk, this also grows luxuriantly at 37°. The souring and spoiling of milk occur very rapidly at this temperature.

These comparisons are in harmony with those of Utz (loc. cit.), and also of Bockhout and de Vries (Cent. f. Bact. II. XII., p. 89, 1904), although obtained by different methods.

7. In milk kept at 10° neither of the types of lactic bacteria seems to be favored. The delay in growth lasts 2 or 3 days, after which all types of bacteria appear to develop somewhat uniformly. Sometimes the lactic bacteria develop abundantly, sometimes only slightly. The neutral bacteria almost always grow rapidly, and the liquefiers, in many cases, become abundant. In time the milk is apt to curdle, commonly with an acid reaction, but it never shows the predominance of *Bact. lactis acidi* found at 20°. At 10°, therefore, the lactic bacteria are not so favorably influenced as at 20°, and they exert no check upon the growth of other bacteria. The milk, therefore, in time becomes more decidedly affected by bacteria than at 20°, and its wholesomeness more under suspicion.

8. From our experiments there seems to be no difference between the effect of 10° and 1° upon the bacteria, except upon the rapidity of growth. 1° very markedly checks the growth of bacteria; but later they grow to great numbers. As at 10°, the lactic bacteria fail to outweigh the other species, so that all types develop abundantly. A few species appear to be particularly well adapted to this low temperature, and are especially abundant at the end of the experiments.

9. The curdling point appears to be quite independent of the number of bacteria present. In one sample, at 37°, the milk curdled with only 8,000,000 per cubic centimeter, while in others there have been found 4,000,000,000 per cubic centimeter without any curdling. These differences are due partly to the development of enzyms, and partly to the products of some species neutralizing the actions of others. The amount of acid present at the time of ordinary acid curdling does not widely vary.

10. Milk is not necessarily wholesome because it is sweet, especially if it has been kept at low temperatures. At the temperature of an ice chest milk may remain sweet for a long time, and yet contain enormous numbers of bacteria, among which are species more likely to be unwholesome than those that develop at 20°. From this standpoint the suggestion arises that instances of ice cream poisoning are perhaps due to the preservation of cream for several days at a low temperature, such treatment keeping the milk sweet, but favoring the development of species of bacteria that are, at higher temperatures, checked by the lactic organisms.

THE SO-CALLED "GERMICIDAL PROPERTY" OF MILK.

BY W. A. STOCKING, JR.

[In the preparation of this report credit is due to Dr. H. W. Conn for aid in planning and conducting the investigation.]

MILK AS A FOOD.

The high nutritive value of milk as a human food is recognized by all, and does not need to be emphasized. Milk may be consumed as a fresh article, or it may be made into butter, cheese, and other manufactured products. The larger part, however, is used for consumption in its natural form. Milk that is to be used for direct consumption must reach the consumer in as nearly its natural condition as possible; that is, the condition in which it leaves the udder of a healthy cow. Every one who is at all familiar with milk knows that if left to itself, certain changes take place within the next few hours after it is drawn from the cow. The most noticeable of these changes is the souring and curdling, a phenomenon so common that all milk handlers and consumers are familiar with it. There are also other changes which take place, which affect the odor and taste and sometimes the appearance of the milk, even though it does not taste sour or appear to be curdled.

During the last few years these various changes in milk have been subject to a large amount of study and investigation, and it is now known that a large part of them, at least, are due to the presence and growth of bacteria in the milk. The practical problem, then, for the dairyman and milk dealer as well as the milk consumer is to so produce and care for the milk that the entrance and development of bacteria will be reduced to the minimum.

MILK CONTAMINATED IN THE UDDER.

Milk as it is secreted in the glands of the healthy udder is free from all micro-organisms. Recent investigations, however, have shown that the milk becomes more or less filled

with bacteria before it is drawn from the udder. This contamination is made possible by reason of the fact that bacteria are able to gain access through the orifice of the teat, thus working their way through the ducts into the various parts of the udder. So universal is this udder contamination, that it is a practical impossibility to obtain milk in a sterile condition. Milk, therefore, may contain quite appreciable numbers of bacteria when it is drawn from the cow; but experiments conducted at this Station and at other places seem to show quite conclusively that the organisms which normally exist in the milk while it is still in the udder produce but slight effects upon the milk, even when it is kept for a number of hours at comparatively warm temperatures. By far the larger part of the bacteria found in milk as it reaches the consumer gain access from external sources, and it is due to the presence and growth of these that the milk undergoes the process of souring, changes in taste and odor, and various decomposition processes. During the past few years a large amount of study and investigation has shown that milk is an excellent medium for the growth of a great variety of species of bacteria. As a result of this, it has become a generally accepted opinion that practically all species of bacteria that gain access to the milk thrive and multiply in it, the rate at which the multiplication takes place being dependent on the temperature at which the milk is kept. The commonly accepted idea has been that the bacteria which are in the milk at the time it is drawn begin immediately to multiply with great rapidity. In order to prevent this enormous increase, the common practise is to cool the milk more or less thoroughly as soon as possible and then keep it at as low a temperature as circumstances permit. In contrast with this generally accepted opinion, certain investigators have from time to time made the statement that for a certain length of time the number of bacteria decreases, so that milk when a few hours old contains a smaller number of organisms than it did when first obtained. This fact was stated by Fokker in 1890, by Freudenreich in 1891, and by Freeman in 1896. These men simply observed that the number of organisms was frequently smaller when the milk was a few hours old than when first drawn, and simply made the statement that "freshly drawn milk contains a germicidal action," but made no attempt to determine the extent of this action or to explain the cause of the phenomenon.

BACTERIA DECREASE IN MILK AFTER DRAWING.

In 1901 Hunziker made an extended series of experiments to determine the presence and intensity of this "germicidal action." His conclusion was that "there is in the freshly drawn milk of some cows a substance or condition that has the power of destroying a certain percentage of the bacteria content; and by so doing the total number of bacteria in the milk is reduced." His observations seemed to show that the action of this germicidal substance or condition varied with the individual cow, and that its duration was influenced by the degree of temperature at which the milk was kept. This germicidal action was most rapid at comparatively high temperatures, and the minimum number of bacteria was reached in a comparatively short time; while at the lower temperatures the intensity of the action was lessened, and its duration was increased, so that the minimum number was reached at a later period. After this minimum had been reached, the germicidal property seemed to act no longer, and the number of organisms increased with great rapidity, the rate of growth being dependent upon the temperature at which the milk was kept. Hunziker's conclusions were based wholly upon results obtained by the determination of the total number of bacteria found in the milk at different periods, as shown by the growth of colonies upon agar plate cultures. While he shows conclusively that there is normally a falling off in the number of organisms during the first few hours, he was unable to explain the cause of this phenomenon.

CERTAIN BACTERIA DO NOT THRIVE IN MILK.

This subject of the germicidal action of milk has been studied in our laboratory, and the results have, in nearly all instances, confirmed the general conclusions reached by Hunziker. There seems to be no doubt that milk obtained under ordinary conditions contains, when a few hours old, a smaller number of bacteria than it did when first obtained from the cow. Hunziker made no attempt to study the development of the various species found in the milk, but based his conclusions upon total numbers simply. The results of studies made in our laboratory upon the growth of different species of bacteria in milk suggested to us that possibly this reduction in numbers might be the result, not of any "substance or power" possessed by

the milk, but simply of the natural dropping out of certain species which did not find the milk a suitable medium in which to live and multiply. Fresh milk obtained under ordinary conditions normally contains a great variety of species of bacteria. Some species of bacteria which gain access to fresh milk do not find it a favorable medium in which to grow, and it has been shown by Conn and others that milk when near the souring and curdling point normally contains but few species of bacteria, often not more than two or three. Somewhere during the intervening time all of the other species disappear. This fact suggested that possibly here might lie the explanation for the so-called "germicidal action." Probably nearly all of the species which gain access at the time of milking would appear in the plates made from the fresh milk. Certain of these species, however, finding milk so entirely different from their natural habitat, might soon lose their vitality, and not appear in plates made at later periods. These would show a smaller number of bacteria in the milk, not as a result of any germicidal property, but simply because some species were unable to live in the conditions afforded by the milk. Among the species gaining access to the milk, there might be those which could not develop in a medium so different from their natural conditions. These might appear in the first plates made from fresh milk, but, being unable to multiply, would have disappeared before the second set of plates was made. Other species, finding the conditions not so distasteful, might multiply for a time, gradually losing their vitality and finally dropping out. Certain other species might find the new conditions well adapted to their needs, and develop with great rapidity from the very start. If such a condition existed, it might frequently happen that the dropping out of the species which could not grow would be greater than the increase of the species which could grow in the milk. This would result in the apparent decrease of the numbers of organisms, or the so-called "germicidal action." In order to prove the truth or falsity of the supposition, it would be necessary to make a study of the species found in the fresh milk and their behavior during the subsequent period through which the so-called "germicidal action" is supposed to exist. The results of former investigations have been based wholly upon numbers, without reference to individual species.

In order to get some data in regard to these problems, the experiments discussed in this article were undertaken by this Station.

METHOD USED IN THESE EXPERIMENTS.

The results considered in these experiments were obtained from the mixed milk of a herd of about thirty cows. It was believed that results which might be obtained from mixed milk would be of greater practical value than results obtained from milk of individual cows, since the mixed milk would contain such organisms as are normally found in ordinary milk, while the milk from individual cows would be more or less influenced by the species which happen to exist in the udder of the particular cow whose milk was used.

As soon as the milk was drawn it was taken to the dairy room and cooled to a temperature of from 35°–40°F., and portions of this cooled milk were then taken to the laboratory for experimentation. A series of plate cultures was made immediately from these cooled samples, the culture media being the milk sugar litmus gelatin which has previously been described by this Station. As soon as the first series of plates was made, the milk was warmed up to 20°C. and held at that temperature until the end of the experiment. This temperature of 20° was chosen as being the most promising of results, since Hunziker found that at this temperature the so-called "germicidal action" was most pronounced. At the end of three hours a second series of plates was made from the sample; at the end of six hours a third series, and likewise at the end of nine and twelve hours. In a few experiments the samples were plated at intervals of two hours, but the results obtained did not differ in any noticeable degree from those obtained by plating every three hours.

In every case six plates were made, using three different dilutions, and the figures given in these results are in each instance the averages of the six plates, so that errors of sampling and manipulation, so difficult to keep out of such work are largely eliminated, and the figures given represent quite accurately the condition of the milk at the time the test was made. The gelatin plates were incubated at a uniform temperature of 20°C., and were, in most cases, not finally studied until they

had developed for six or seven days. Occasionally the presence of rapid liquefiers made it necessary to study the plates somewhat earlier. Experience has shown that the various species can be differentiated much more accurately when the colonies have developed for about a week, and it was for this reason that the plates were studied at this time, though the total numbers might have been obtained somewhat sooner. When the plates were properly developed, they were carefully studied and the following determinations made:

1. The total number of bacteria.
2. The total number of acid producing bacteria.
3. The total number of non-acid bacteria.
4. The total number of liquefying bacteria.
5. The predominating species.

In each experiment the predominating species in the acid producing group, and also in the non-acid group, were isolated, and later were carried through the various cultures in order to identify the species. This was necessary in order to determine definitely whether or not certain species disappear, while others increase, during the period covered by the so-called "germicidal action;" and special care was taken to determine the acid species present.

It will be seen by a study of the results obtained that this work of differentiating types of organisms, especially of the lactic acid producing ones, was especially important, since it reveals the fact that certain species are not affected by the germicidal theory, while others are decidedly so affected.

About twenty experiments have been conducted, and the results are quite uniform. In almost every case there is a falling off in the total number of the organisms present, during the first few hours. This will be seen by a study of Tables 28, 29, and 30.

NUMBERS OF BACTERIA DECREASE.

It may be seen by a study of these tables that in nearly all cases there appears to be a reduction in the number of bacteria during the first few hours after the milk was obtained, or, in other words, nearly all of the milk tested showed the presence

TABLE 28.

No. of Experiment.	Total Bacteria.	Decrease in 3 hours.	Per Cent. Decrease.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.
Fresh Milk.						
1,	12,550	—	—	1,250	10	200
2,	5,483	—	—	467	8	1,625
3,	7,625	—	—	—	—	—
4,	3,217	—	—	558	17	313
5,	5,090	—	—	1,429	28	8
6,	7,138	—	—	3,090	43	805
7,	11,167	—	—	2,135	19	1,117
8,	3,304	—	—	1,075	33	405
9,	2,542	—	—	375	15	365
10,	4,221	—	—	1,130	27	220
11,	6,050	—	—	900	15	1,031
12,	13,583	—	—	1,150	8	1,650
Average,	6,832	—	—	1,232	20	703
3 hours.						
1,	12,250	300	2.4	2,000	16	200
2,	5,183	300	5.5	175	17	1,842
3,	3,625	—	—	467	13	375
4,	3,667	*450	*14.	869	24	145
5,	9,746	*4,648	*91.2	988	10	25
6,	6,033	1,105	15.5	2,500	41	800
7,	—	—	—	—	—	217
8,	2,700	604	18.3	975	35	—
9,	2,310	232	9.1	610	26	265
10,	4,617	*396	*9.4	1,225	27	280
11,	4,445	1,595	26.3	667	15	567
12,	12,279	1,304	9.6	—	—	—
Average,	6,224	—	—	1,118	22	472
6 hours.						
1,	19,650	—	—	2,250	23	800
2,	5,900	—	—	1,380	23	1,300
3,	6,325	—	—	—	—	—
4,	12,000	—	—	820	7	475
5,	99,000	—	—	4,300	4	120
6,	8,275	—	—	3,180	38	1,375
7,	22,917	—	—	2,575	11	1,200
8,	4,442	—	—	1,800	41	460
9,	2,775	—	—	675	24	275
10,	6,100	—	—	1,963	32	338
11,	6,125	—	—	1,860	30	1,110
12,	11,517	—	—	1,950	13	2,713
Average,	17,435	—	—	2,068	22	924
9 hours.						
1,	56,900	—	—	20,250	36	550
2,	38,125	—	—	3,150	8	2,625
3,	18,750	—	—	5,500	45	1,313
4,	25,350	—	—	475	2	325
5,	1,568,000	—	—	5,958	0	825

*Increase.

TABLE 28—*Continued.*

No. of Experiment.	Total Bacteria.	Decrease in 3 hours.	Per Cent. Decrease.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.
9 hours—Continued.						
6, - - - - -	14,500	—	—	4,000	28	3,525
7, - - - - -	71,708	—	—	9,625	13	2,938
8, - - - - -	10,775	—	—	3,938	37	938
9, - - - - -	6,250	—	—	1,625	26	525
10, - - - - -	5,021	—	—	1,458	29	563
11, - - - - -	5,958	—	—	1,625	27	1,400
12, - - - - -	—	—	—	—	—	—
Average, - - -	165,576	—	—	5,509	23	1,411
12 hours.						
1, - - - - -	114,250	—	—	68,400	60	1,900
2, - - - - -	256,667	—	—	5,417	2	4,917
3, - - - - -	79,500	—	—	1,250	2	6,250
4, - - - - -	—	—	—	—	—	—
5, - - - - -	6,729,000	—	—	10,250	0	4,000
6, - - - - -	41,938	—	—	7,500	18	17,312
7, - - - - -	172,833	—	—	20,000	12	3,000
8, - - - - -	28,042	—	—	14,900	53	2,155
9, - - - - -	20,850	—	—	5,167	25	2,667
10, - - - - -	—	—	—	—	—	—
11, - - - - -	—	—	—	—	—	—
12, - - - - -	—	—	—	—	—	—
Average, - - -	930,385	—	—	16,610	22	5,274

of the so-called "germicidal action." The amount of the decrease varies greatly in the different experiments. Not infrequently more than 50 per cent. of the bacteria present in the fresh milk had disappeared at the time when the organisms had reached the minimum. Frequently, however, the decrease was very slight, and a few experiments show no decrease whatever, but on the contrary a continuous increase. This fact does not prove, however, that there was no decrease, for it may have taken place between the periods when the plates were made, so that its appearance was lost by our method of work. As previously stated, the samples from which the figures in Tables 28 and 29 were obtained were kept at a constant temperature of 20°C., and, as might be expected, the decrease in numbers reached the minimum at a comparatively early hour, in most cases the plates made at the end of three hours showing the smallest numbers. In two instances, experiments 4 and 5, in Table 29, the minimum was not reached until the milk was eight hours old, there being a somewhat gradual decrease up to that time.

TABLE 29.

No. of Experiment.	Total Bacteria.	Decrease in 2 hours.	Percentage Decrease.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh Milk.						
1,	19,300	—	—	2,600	13	1,600
2,	11,738	—	—	2,400	20	950
3,	7,145	—	—	2,000	28	400
4,	9,250	—	—	3,206	35	425
5,	1,463	—	—	919	42	73
Average,	9,779	—	—	2,165	28	690
2 hours.						
1,	18,938	362	1.9	2,800	15	2,000
2,	10,758	980	8.3	2,425	23	825
3,	8,300	*1,155	*16.1	2,075	25	450
4,	9,275	*25	*.3	3,796	41	346
5,	1,600	*137	*9.3	713	45	63
Average,	9,774	—	—	2,362	30	737
4 hours.						
1,	22,083	—	—	3,600	16	2,200
2,	9,825	—	—	2,900	31	738
3,	8,383	—	—	2,967	35	525
4,	7,442	—	—	3,960	53	290
5,	1,333	—	—	645	48	60
Average,	9,813	—	—	2,814	37	763
6 hours.						
1,	29,850	—	—	—	—	—
2,	10,392	—	—	2,820	27	1,060
3,	13,533	—	—	3,467	26	550
4,	7,592	—	—	3,317	44	267
5,	1,379	—	—	721	52	113
Average,	12,549	—	—	2,581	37	798
8 hours.						
1,	52,979	—	—	—	—	—
2,	12,271	—	—	4,188	34	4,000
3,	10,375	—	—	2,792	27	475
4,	7,250	—	—	3,225	45	396
5,	1,117	—	—	460	41	40
Average,	16,798	—	—	2,666	37	1,228

*Increase.

The principal value of these tables lies in the fact that they show an actual decrease in the number of bacteria present until a certain minimum is reached, after which the increase is comparatively rapid. The results obtained can be intelligently discussed in their relation to our subject only in connection with a discussion of the species found in each sample of milk. Such a detailed discussion of individual experiments will be taken up later.

TABLE 30.

Samples kept at temperature of 50° F.

No. of Experiment.	Total Bacteria.	Difference.	Percentage Decrease.	Acid Bacteria.	Per Cent. Acid Bacteria.	Liquefying Bacteria.
Fresh Milk.						
1,	3,950	—	—	800	20	487
2,	60,616	—	—	316	1	1,216
3,	2,862	—	—	525	18	300
4,	112	—	—	13	11	—
5,	487	—	—	125	26	13
6,	70	—	—	30	43	—
7,	755	—	—	270	36	290
Av. of exp's. 1, 2, 3,	22,476	—	—	547	10	668
Av. of exp's. 4, 5, 6, 7,	356	—	—	109	29	76
12 hours.						
1,	1,613	2,337	59.1	800	50	150
2,	3,600	57,016	94.0	400	11	800
3,	2,237	625	21.8	517	23	225
4,	19	93	83.0	13	68	—
5,	337	150	30.8	137	41	37
6,	38	32	45.7	13	34	—
7,	575	180	23.8	125	22	75
Av. of exp's. 1, 2, 3,	2,483	19,993	58.3	572	28	392
Av. of exp's. 4, 5, 6, 7,	242	114	45.8	72	41	28
24 hours.						
1,	13,550	—	—	12,850	95	100
2,	109,066	—	—	666	1	3,100
3,	20,250	—	—	17,166	85	1,625
4,	50	—	—	25	50	—
5,	400	—	—	200	50	100
6,	50	—	—	13	26	25
7,	22,717	—	—	13,716	60	325
Av. of exp's. 1, 2, 3,	47,622	—	—	10,227	60	1,608
Av. of exp's. 4, 5, 6, 7,	5,804	—	—	3,488	48	112

The experiments shown in Table 30 were made for the purpose of comparing the relative decrease of the bacteria in samples of milk containing large and small numbers of bacteria and to note the retarding effect of the lower temperature. The first three samples were obtained in the ordinary manner without special effort to exclude bacteria; the last four were so taken that the external contamination was reduced quite materially. Comparison of the first three with the last four experiments reveals the fact that samples containing the larger numbers of bacteria suffered a greater reduction in numbers than did those samples containing the smaller numbers. This

fact will be explained in the more detailed discussion of individual experiments later. Our experiments thus far have, in the more essential points, verified the points given by previous investigators on this question, and it is not our purpose in this paper to discuss the question of the decrease of bacteria in milk during the first few hours after leaving the cow. There can be but little question that such a decrease is the normal occurrence in ordinary milk. The purpose of these experiments is rather to investigate the *cause* of this phenomenon, and the results certainly throw considerable light upon the subject.

A study of the species found in the experiments made thus far enables us easily to divide them into three general groups according to the way in which the various species behave themselves. The first group includes those experiments in which there was a decided reduction in the total number of bacteria during the first few hours, but at the same time a continuous increase in the acid producing bacteria from the very first, both in actual numbers and in percentage. In the second group are placed those experiments in which there was a more or less marked reduction in the total number of bacteria and also a reduction in the number of acid producing organisms during the first few hours until the minimum was reached, after which both the acid and non-acid producing species increased more or less rapidly. In the third group are included those results which showed a reduction in the total number of bacteria in the first few hours, accompanied by a continuous increase in the number of acid producing species, but at the same time a decrease in the percentage of the acid organisms.

DISCUSSION OF GROUP I.

The experiments of the type included in Group I. may be illustrated by the following tables representing two individual experiments.

Table 31 shows that there was a decrease in the total number of organisms in the first few hours. The fresh milk contained 12,550 bacteria, while at the end of three hours there were 12,250, showing a decrease of 300 organisms, or 2.4 per cent. In the fresh milk there were 1,250 of the acid producing species, or 10 per cent. of the organisms present. At the end of three hours the milk contained 2,000 acid producing bacteria

TABLE 31.

Age of Milk.	Total Bacteria.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh, - - - - -	12,550	1,250	10	200
3 hours, - - - - -	12,250	2,000	16	200
6 hours, - - - - -	19,650	2,250	23	800
9 hours, - - - - -	56,900	20,250	36	550
12 hours, - - - - -	114,250	68,400	60	1,900

TABLE 32.

Age of Milk.	Total Bacteria.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh, - - - - -	2,542	375	15	365
3 hours, - - - - -	2,310	610	26	265
6 hours, - - - - -	2,775	675	24	275
9 hours, - - - - -	6,250	1,625	26	525
12 hours, - - - - -	20,850	5,167	25	2,667

per cubic centimeter, showing an increase during this period of 750. The acids at this time constituted 16 per cent. of the total number. This means, then, that while there was an actual decrease in the total number of organisms present in the milk, this was not brought about by a dropping out of all of the different species, but of certain of the non-acid producing ones, since the acid organisms increased from the very outset. During these first three hours, while the acid organisms were increasing 750, the non-acid species decreased 1,050. At the end of six hours the total number had risen to 19,650, and continued to increase with considerable rapidity throughout the remainder of the experiment. At the end of six hours the number of acids had risen to 2,250, and now comprised 23 per cent. of the total number. At the end of nine hours they constituted 36 per cent., and at the end of twelve hours 60 per cent. of all the organisms present. The non-acid organisms found in this sample of milk were a miscellaneous lot of organisms, which apparently did not find the conditions afforded by milk suitable for their development. They, therefore, did not

thrive in it, and, as the experiment shows, certain species dropped out quite rapidly during the first few hours. The number of acid producing species found in the fresh milk was unusually small in this experiment, and were mainly of the species *Bact. lactis acidi* (Leichmann). These appeared in small numbers in the plates made from the fresh milk, together with a few miscellaneous acid organisms. The *Bact. lactis acidi* was the only species which increased in numbers, its growth being quite uniform and so rapid that at the end of twelve hours it constituted 60 per cent. of all the organisms present, and was the only acid to be found. A study of Table 32 shows the same condition as has been brought out in the discussion of Table 31, the principal difference in this case being the species of acid found in the milk. In the fresh milk the acids were made up of *B. lactis aerogenes*, together with a number of miscellaneous species. The miscellaneous ones did not increase materially, while *B. lactis aerogenes* increased steadily from the outset, where it comprised 15 per cent. of the total number, until at the end of twelve hours it made up 25 per cent. of the organisms present, a much less rapid increase, it will be noticed, than was made by *Bact. lactis acidi*, but nevertheless an actual and continuous increase from the very start.

These experiments would seem to show that while the number of bacteria decreased to a greater or less extent during the first few hours, the decrease was simply a natural result of the fact that certain species which had gained access to the milk found it a poor medium in which to develop, and therefore disappeared; while the true lactic organisms, which find in milk conditions well suited to their liking, increased continuously from the very outset. These results would seem to warrant the conclusion, therefore, that there is no "property or condition" in the milk which is germicidal, the decrease in numbers being the natural result of ill suited environment.

DISCUSSION OF GROUP II.

This group, as previously stated, contains those experiments where both the total number and the number of acid producing organisms showed a reduction during the first few hours, later

followed by an increase in the numbers of both the acid and the non-acid producing species. This type of results may be shown by the two experiments given in Tables 33 and 34.

TABLE 33.

AGE OF MILK.	Total Bacteria.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh, - - - - -	3,300	1,075	33	405
3 hours, - - - - -	2,700	975	35	217
6 hours, - - - - -	4,442	1,800	41	460
9 hours, - - - - -	10,775	3,938	37	938
12 hours, - - - - -	28,042	14,900	53	2,150

TABLE 34.

AGE OF MILK.	Total Bacteria.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh, - - - - -	7,138	3,090	43	805
3 hours, - - - - -	6,033	2,500	41	800
6 hours, - - - - -	8,275	3,180	38	1,375
9 hours, - - - - -	14,500	4,000	28	3,525
12 hours, - - - - -	41,938	7,500	18	17,312

The behavior of the total numbers of organisms in these experiments is similar to that in the preceding ones, the principal difference being in the behavior of the acid producing organisms. In both experiments the decrease in the total number of organisms during the first three hours was accompanied by a similar decrease in the number of acid producing species. As seen in the first table, the acids decreased from 1,075, or 33 per cent. of the total number, to 975, or 35 per cent. of the total; and in the second experiment the decrease was from 3,090 to 2,500. In this case there was also a decrease in the percentage of acids from 43 to 41. By the end of six hours the numbers of both the non-acid and acid producing types had commenced to increase, and continued to do so throughout the experiment. It is principally the types of acid organisms found

in these experiments which makes them differ from the experiments previously discussed. In the first two experiments either *Bact. lactis acidi* or *B. lactis aerogenes* was shown to exist in the fresh milk. In the present experiments, however, the acid organisms consisted of miscellaneous species, and none of the typical lactic types showed themselves in the plates. Several of the acid species found in the fresh milk disappeared before the end of the experiment, other species remained about the same in numbers, while others which did not appear in the first plates formed the predominating acid species at the close. The two chief lactic acid types, namely *B. lactis aerogenes* and *Bact. lactis acidi*, began to appear in the plates made at the end of six hours, and increased continuously until at the end of the experiment these two types comprised the greater part of the acids present. There were also, however, a few of some of the other species present.

The results of these experiments seem to show that the true lactic organisms were present in the fresh milk in such small numbers that they did not appear in the first set of plates, but were there in sufficient numbers to make themselves known by the end of six hours, and became more and more abundant from then on. It is evident, therefore, that they increased from the outset as in the preceding experiments. The further fact is here revealed that certain other acid producing species do not find in milk conditions especially favorable for their development. They therefore drop out with greater or less rapidity during the early part of the ripening period. In milk where this condition exists, the decrease in the number of the miscellaneous acid species may be greater than the increase in the number of the true lactic acid species, and the result will be a smaller number of acid organisms than was contained in the fresh milk.

DISCUSSION OF GROUP III.

In this group are included experiments where the results were of quite a different nature from those included in the first two groups.

In these experiments there was usually a falling off in the total number of organisms during the first few hours, as in the preceding experiments. Sometimes the acid organisms increased in numbers from the very start, as shown in Table 35,

TABLE 35.

AGE OF MILK.	Total Bacteria.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh, - - - - -	5,483	467	8	1,625
3 hours, - - - - -	5,183	875	17	1,842
6 hours, - - - - -	5,900	1,380	23	1,300
9 hours, - - - - -	38,125	3,150	8	2,625
12 hours, - - - - -	256,667	5,417	2	4,917

TABLE 36.

AGE OF MILK.	Total Bacteria.	Acid Bacteria.	Percentage Acid Bacteria.	Liquefying Bacteria.
Fresh, - - - - -	5,098	1,429	28	8
3 hours, - - - - -	9,746	988	10	25
6 hours, - - - - -	99,000	4,300	4	120
9 hours, - - - - -	1,568,000	5,958	0	825
12 hours, - - - - -	6,729,000	10,250	0	4,000

and sometimes there was a decrease for the first few hours, as shown in Table 36. The principal point in which these results differ from those already described is in the unusually rapid development of the non-acid organisms and the accompanying decreasing percentage of the acid species. A study of Table 35 shows that the total number of organisms was smaller at the end of three hours than in the fresh milk. At the end of six hours it had increased slightly, but at nine and twelve hours the numbers had increased with great rapidity, amounting to 256,667 organisms when the milk was twelve hours old. In Table 36 a study of the total numbers shows the increase to have been even more rapid, the bacteria at the end of twelve hours having reached the enormous number of 6,729,000. This is, of course, a very high number for milk of that age. A glance at the columns showing the acid species reveals the fact that the increase was comparatively slow in both of the experiments here given. In Table 35 this increase was continuous from the very start, while there was a small decrease at the end of three hours in Table 36, after which the increase was quite marked.

The striking features shown in these tables is the percentage of acid organisms, which decreases toward the end of the experiment instead of increasing as in the experiments described earlier; in one case amounting to only 2 per cent. at the end of twelve hours and in the other to but a fraction of 1 per cent. This decrease in the percentage of acid organisms is, of course, due to the unusually rapid increase in the total numbers in comparison with the increase of the acid organisms. The explanation of the condition of these samples of milk is found in a study of the species contained. In each of these samples, a single species of organism, which was not an acid producer, but, on the contrary, produced a strong alkaline condition in the medium, developed with unusual rapidity throughout the experiments. In Table 35 this organism constituted 15 per cent. of the total number in the fresh milk. At the end of three hours it had increased to 19 per cent., at the end of six hours to 28 per cent. and at the end of nine hours to 32 per cent., while at the end of twelve hours it had increased with such rapidity that 167,500, or 60 per cent. of all the organisms present were of this one species. Upon isolation and later study this organism proved to be identical or very closely related to No. 126 of Conn.

In Table 35 the acid species in the fresh milk consisted of *Bact. lactis acidi* and a few miscellaneous species. These increased continuously, *B. lactis aerogenes* appeared during the experiment, and these two types comprised most of the acids at the end of twelve hours. In Table 36 the acids in the fresh milk were of quite a miscellaneous nature, the principal species being Nos. 168 and 137 of Conn. None of the real lactic organisms appeared in the first set of plates. During the first few hours most of the miscellaneous acid organisms disappeared more or less completely, while the two species named continued throughout the experiment. *Bact. lactis acidi* made its appearance after the first few hours, and plates made at the end of three days revealed the fact that the acid organisms were practically all of this species, the others having disappeared during that time.

These experiments represent what may be considered as irregularities in the normal development of bacteria in milk. Here the unusual development of a single non-acid species not

8

only reduced the percentage of acid producing organisms, but apparently even retarded the increase in the actual numbers. Possibly the fact that they were strongly alkaline in their action upon media may have had a checking influence upon the acid species. However, the lactic acid species finally gained the ascendency, so that when plated at the end of three days they constituted by far the larger part of all the organisms present.

The results of the experiments thus far conducted on this subject point quite conclusively to the following:

1. Milk produced under ordinary conditions becomes contaminated with considerable, frequently very large, numbers of bacteria. These organisms come from various sources, and comprise a large number of species.

2. Many of the species gaining access to the milk find the conditions so different from their natural habitat that they are not able to multiply, and therefore they drop out very soon. Others which find the conditions not quite so unfavorable can multiply slowly for a time, but, gradually losing their vitality, disappear.

3. Other species which gain access to the milk find the conditions well suited to their development, and multiply more or less rapidly and continuously from the very start. The lactic acid species, *Bact. lactis acidi* and *B. lactis aerogenes*, together with certain non-acid species, come within this group.

4. The decrease in the numbers of bacteria during the first few hours is not the result of any "germicidal condition or property" possessed by the milk, but simply of the natural dropping out of those species which do not find the milk a suitable medium in which to develop.

5. When fresh milk contains the typical lactic organisms, namely *Bact. lactis acidi* and *B. lactis aerogenes*, even in very small numbers, they may be expected to increase continuously from the very outset. Immediate cooling is therefore necessary if the growth of these species is to be checked.

6. Numerous other acid species which get into fresh milk do not find it well suited to their development, and disappear more or less completely during the ripening period.

THE FOOD VALUE OF A POUND OF MILK SOLIDS IN MILK POOR AND RICH IN FAT CONTENT.

BY C. L. BEACH.

The milk of the cow is used for butter making, cheese making, and for direct consumption. The butter maker and the cheese maker usually pay for milk according to its fat content, and the consumer pays by the quart. Theoretically the butter maker might pay a slight premium for fat in rich milk, as there is relatively less loss in manufacture. The cheese maker might consider both the casein and fat content of milk, if a convenient test for the former constituent were at hand. The present method, however, of paying for milk for butter and cheese making at a uniform price per pound of fat works little injustice to the producer.

In the country at large, the product of about one cow in five is sold to be consumed as whole milk. In Connecticut, it is estimated that two-thirds of the milk produced is sold for direct consumption. The bulk of the milk in any one section brings a uniform price per quart. It will not be denied that milk varies in its food value and in its composition, and that its sale at a uniform price per quart works an injustice to both producer and consumer.

TABLE 37.—*Variation in composition of cows' milk.*

QUANTITY OF MILK.	Total solids.	Fat.	Casein and Albumen.	Milk sugar and Ash.
Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
100, - - - - -	11	3.07	2.92	5.01
100, - - - - -	12	3.50	3.07	5.43
100, - - - - -	13	3.99	3.30	5.71
100, - - - - -	14	4.68	3.57	5.75
100, - - - - -	15	5.38	4.00	5.62
100, - - - - -	16	6.00	4.30	5.70

Variation in composition of cows' milk.—By averaging over 2400 American analyses, the Vermont Station (Report 1890, p. 97) found the relationship of the solid ingredients to each other in milk containing different percentages of fat.

Table 37 shows that as the solids increase in mixed milk the various ingredients increase also, but not all in the same proportion. The total solids increase from 11 pounds to 16 pounds in 100 pounds of milk, or 45 per cent.; the fat increases from 3.07 pounds to 6 pounds, or 95 per cent.; the casein and albumen increase from 2.92 pounds to 4.30 pounds, or 47 per cent.; and the milk sugar and ash, from 5.01 pounds to 5.70 pounds, or 13 per cent.

TABLE 38.

Amount of ingredients in 100 pounds of total solids.

QUALITY OF MILK AS TO TOTAL SOLIDS.	Fat.	Casein and Albumen.	Milk sugar and ash.
Per Cent.	Lbs.	Lbs.	Lbs.
11,	27.9	26.5	45.5
12,	29.1	25.6	45.2
13,	30.7	25.4	43.9
14,	33.4	25.5	41.2
15,	35.8	26.6	37.4
16,	37.5	26.8	35.6

Table 38 shows the pounds of ingredients in 100 pounds of total solids in milk of varying quality. The fat increases from 27.9 to 37.5 pounds, the milk sugar and ash decrease from 45.5 to 35.6 pounds, while the casein and albumen remain about one-quarter of the total solids.

Table 39 shows that the muscle forming material and the material that might be used in the body for protein protection are about the same in all milk solids. The number of calories and the value of the solids for fat formation increase with the increase of the milk's per cent. in fat.

Few if any experiments have been made showing the food value of milk poor in fat as compared with milk relatively rich in fat. No data are at hand upon which to base an opinion concerning the food value of a pound of milk solids from milk

TABLE 39.

Theoretical value in 100 pounds of total solids in milk.

Quality of Milk as to Total Solids.	Muscle forming material.	Value of Non-nitrogenous Material. For protection of protein from consumption.	For heat production.	For fat formation.
Per cent.	Lbs.	Lbs.	Calories.	Lbs.
11, - - - - -	26.5	73.4	202,368	94.3
12, - - - - -	25.6	74.3	206,874	96.1
13, - - - - -	25.4	74.6	211,208	97.6
14, - - - - -	25.5	74.6	217,580	99.6
15, - - - - -	26.6	73.2	221,540	100.0
16, - - - - -	26.8	73.1	224,466	101.2

of varying quality. There is a vague, but more or less general opinion among farmers that the calf and perhaps other young animals will make more satisfactory growth when fed whole milk relatively poor in fat. City ordinances and state laws on the contrary discriminate, but not intentionally, against milks low in per cent. of solids and fat. The demand of the retail trade is for milk showing a large percentage of cream. It has been urged by some that the distributor should be called upon to certify to the quality of milk offered for sale. If such a method should be adopted, a knowledge of the food value of milks of different quality would be desirable.

The following experiments were conducted for the purpose of showing the relative food value of solids from milk poor and rich in fat content when fed to young growing animals:

Table 40 shows gains made for four calves fed new milk. Calf No. 3, fed 53 days, required 1.33 pounds of total solids from milk testing 5.1 per cent., against 1.16 pounds for Calf No. 1, fed milk testing 3.27 per cent. fat, for 63 days. Calves Nos. 2 and 4, each fed 30 days, required respectively .91 pounds of total solids from 3.27 per cent. milk and 1.03 pounds of total solids from 4.6 per cent. milk. These calves were not fed for veal, but were designed for dairy calves, and were fed accordingly.

TABLE 40.

Solids for one pound of gain with calves.

	Milk Poor in Fat. 3.27%		Milk Rich in Fat. 5.1%	4.6%
	Calf No. 1.	Calf No. 2.	Calf No. 3.	Calf No. 4.
	Lbs.	Lbs.	Lbs.	Lbs.
Wt. of calves at beginning of trial, -	66.5	45.	67.	58.5
Wt. of calves at end of trial, - -	133.5	79.	126.	94.
Total gain of calves, - - - -	67.	34.	59.	35.5
Number of days fed, - - - -	63.	30.	53.	30.
Gain of calf per day, - - - -	1.06	1.13	1.11	1.18
Pounds of milk consumed, - - -	697.	277.	562.	267.
Pounds of milk solids consumed, -	777.97	30.9	78.48	35.68
Solids for one pound of gain, - -	1.16	.91	1.33	1.03
Solids for 1 lb. gain, average of each pair, lbs., - - - - -	1.03		1.18	

Solids required for one pound of gain with pigs.—Table 41 shows, in the upper division, the gains made by pigs when fed milk ad libitum. For the first 40 days the pair receiving skim milk gained 62 pounds; the pair receiving milk poor in fat, 54.8 pounds; and the pair receiving milk rich in fat, 42.2 pounds. For the next ten days the gain was for each pair 22 pounds, 20½ pounds, and 3½ pounds respectively. From 50 to 60 days the results were 20 pounds gain, 21 pounds gain, and 6 pounds loss respectively.

The second division of the table shows the amount of milk consumed by the pigs at different periods. After 40 days of feeding the pair receiving the milk rich in fat were affected with loss of appetite and diarrhea, and finally did not consume enough to sustain life. The pair receiving milk poor in fat content, as well as those receiving skim milk, maintained good appetites until the close of the trial.

The third division of the table shows the pounds of solids required for one pound of gain. For the first 40 days of feeding the pair receiving the milk poor in fat made one pound of gain from 1.36 pounds of solids in the milk, against 1.78 required for the pair receiving milk rich in per cent. of fat.

For the next two periods of 10 days each the pair receiving the whole milk low in fat made gains from less amounts of solids than did those receiving skim milk, while those that received the milk rich in per cent. of fat made gains in only one instance.

TABLE 41.

Lot I. Milk fed to pigs ad libitum—effect on digestion.

	Skim Milk.	Milk Poor in Fat. 3.54%		Milk Rich in Fat. 5.2%	
	Pigs Nos. 5 and 6.	Pig No. 1.	Pig No. 2.	Pig No. 3.	Pig No. 4.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wt. of pigs at beginning,	19.0	16.0	19.2	17.4	17.9
Wt. of pigs at end of 10 days,	—	19.0	23.9	21.4	22.8
Wt. of pigs at end of 20 days,	—	26.2	30.2	29.1	27.4
Wt. of pigs at end of 30 days,	—	31.0	40.5	34.5	32.5
Wt. of pigs at end of 40 days,	50.	40.0	50.0	40.5	37.0
Wt. of pigs at end of 50 days,	61.	48.5	62.0	45.5	35.5
Wt. of pigs at end of 60 days,	71.	58.0	73.5	40.5	34.5
Wt. of pigs at end of 70 days,	82.	—	—	—	—
Milk fed first 40 days,	—	285	346	271	238
Milk fed from 40 to 50 days,	184	99	114	73	54
Milk fed from 50 to 60 days,	261	134	176	54	23
Milk fed from 60 to 70 days,	316	—	—	—	—
Solids for 1 lb. of gain, 40 days,	—	1.34	1.38	1.72	1.83
Solids for 1 lb. of gain, 40 to 50 days,	1.48	1.30	1.06	2.00	*
Solids for 1 lb. of gain, 50 to 60 days,	2.30	1.57	1.71	*	*
Solids for 1 lb. of gain, 60 to 70 days,	2.32	—	—	*	*

*Loss in weight.

Second trial with pigs.—Table 42 gives the results of a second trial with pigs fed whole and skim milk ad libitum. The pair receiving skim milk gained 72 pounds in 30 days, the pair receiving poor milk, 58 pounds, and the pair receiving rich milk, 50 pounds.

The pigs receiving skim milk required 1.48 pounds of total solids for one pound of gain, the pair receiving poor milk, 1.40, and the pair receiving rich milk, 1.56 pounds. The trial was closed at the end of 30 days, and pigs Nos. 3 and 6 were slaughtered.

Fig. 1. Pig No. 6, fed skim milk. Lot I.

Fig. 2. Pig No. 2, fed milk poor in fat. Lot I.

Fig. 3. Pig No. 3, fed milk rich in fat. Lot I.

TABLE 42.

Lot II. Milk fed to pigs ad libitum.

	Skim Milk.		Milk Poor in Fat. 3.3%		Milk Rich in Fat. 5.7%	
	Pig No. 1.	Pig No. 2.	Pig No. 3.	Pig No. 4.	Pig No. 5.	Pig No. 6.
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Wt. of pigs at beginning, - -	29	30	31	34	28	33
Wt. of pigs at end of 10 days, -	42	42	43	45	40	46
Wt. of pigs at end of 20 days, -	50	49	50	56	50	54
Wt. of pigs at end of 30 days, -	68	63	55	68	51	60
Total gain in weight, - -	39	33	24	34	23	27
Total milk consumed, - -	588.	573.	316.	370.	280.	251.
Total solids consumed, - -	53.9	52.5	36.8	43.2	40.7	36.5
Solids for 1 lb. gain, - - -	1.38	1.59	1.53	1.27	1.77	1.35
Average for each pair, - -	1.48		1.40		1.56	

Result of slaughter.—The skim milk fed pig dressed 65 per cent. of its live weight, and the rich milk fed pig, 70 per cent. The weight of liver, spleen, and blood was practically the same. The sixth rib of each pig was dissected out and analyzed with the following results: There was 21.25 per cent. of fat in the skim milk fed pig, which is about the amount found by Lawes and Gilbert in the "Store Pig." The whole milk fed pig contained 35.68 per cent. of fat. The skim milk fed pig had 1.78 per cent. more lean meat and 11.93 per cent. more water, and 14.43 per cent. less fat.

Fig. 4. Pig No. 1, fed skim milk. Lot II.

Fig. 5. Pig No. 3, fed milk poor in fat. Lot II.

Fig. 6. Pig No. 5, fed milk rich in fat. Lot II.

Fig. 7. Pig No. 2, fed skim milk. Lot II.

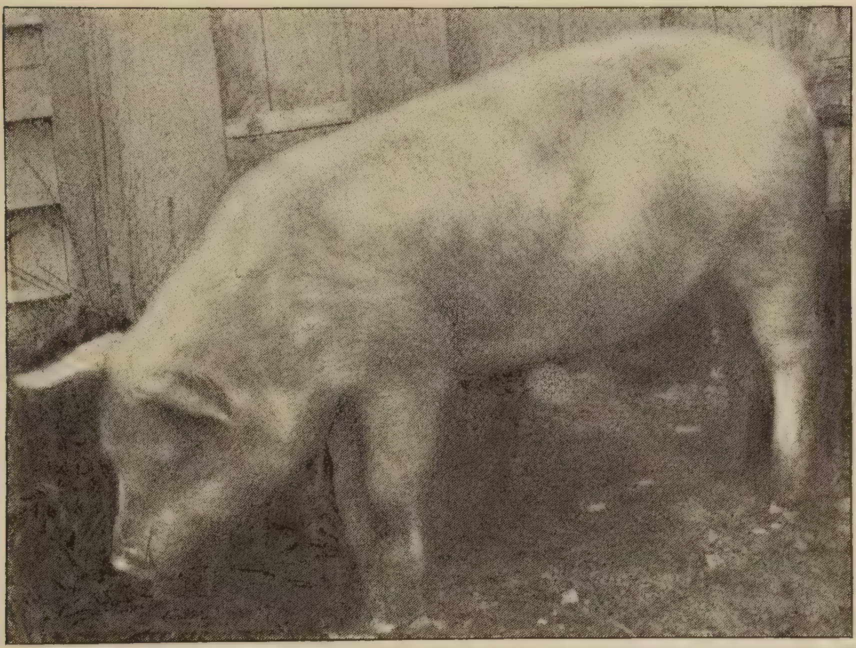


Fig. 8. Pig No. 4, fed milk poor in fat. Lot II.

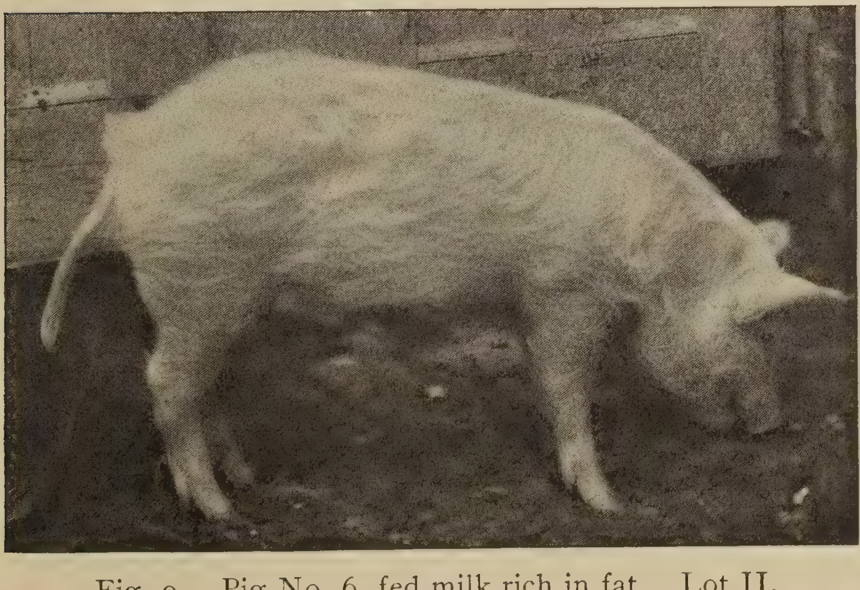


Fig. 9. Pig No. 6, fed milk rich in fat. Lot II.

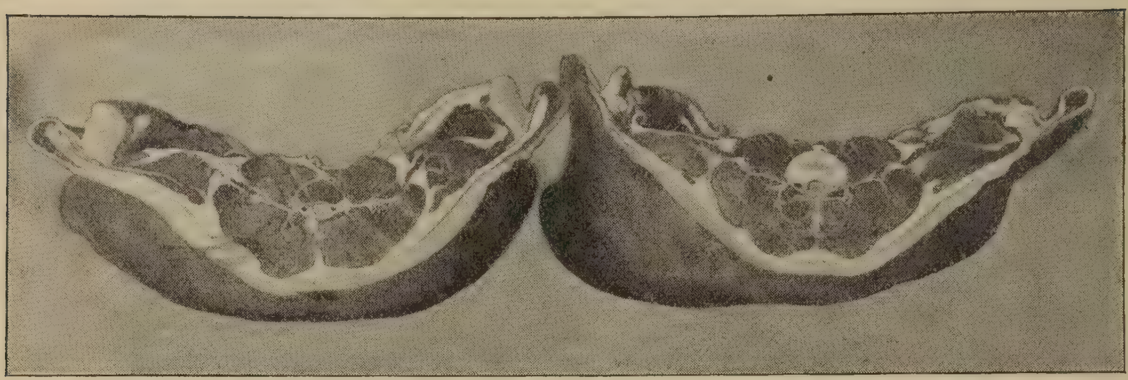


Fig. 10. Showing distribution of fat in carcass of pigs fed skim milk and rich milk—the latter on the left.

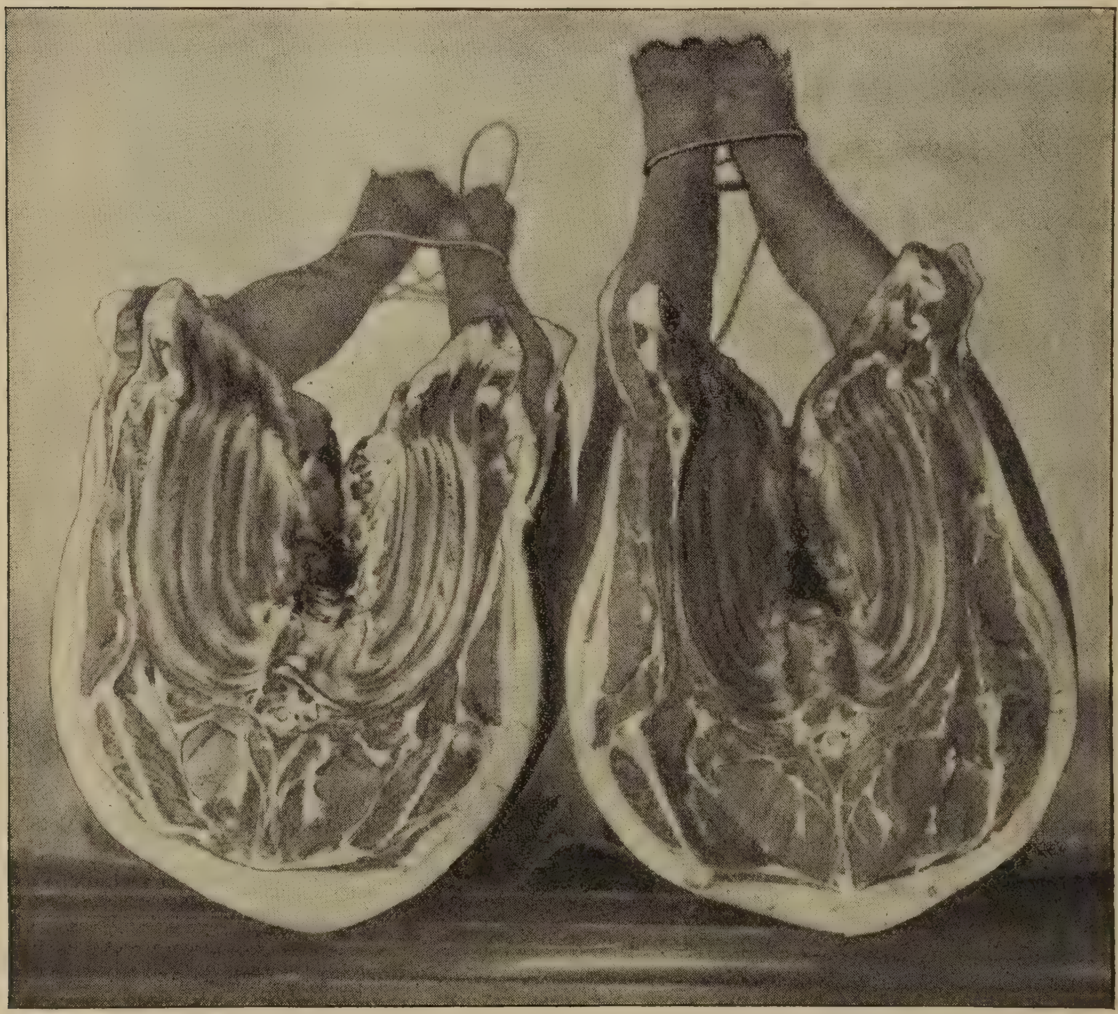


Fig. 11. Showing the distribution of fat in carcass of pigs fed skim milk and rich milk—the latter on the left side.

TABLE 43.

Analysis of sixth rib.

	Skim Milk Fed Pig No. 2.			Whole Milk Fed Pig No. 6.		
	Found in Lean Meat and Fatty Tissue.	Estimated in Skin and Bone.	Total.	Found in Lean Meat and Fatty Tissue.	Estimated in Skin and Bone.	Total.
Protein, - - - -	10.60	3.36	13.96	9.23	2.95	12.18
Fat, - - - - -	19.63	1.62	21.25	34.28	1.40	35.68
Water, - - - - -	49.26	9.20	58.46	39.50	7.03	46.53
Ash, - - - - -	.59	3.32	3.91	.52	2.95	3.47
Undetermined, - -	.56	—	.56	.38	—	.38
Loss (chiefly water), -	1.86	—	1.86	1.76	—	1.76
	82.50	17.50	100.00	85.67	14.33	100.00

TABLE 44.

Gains from lambs fed whole milk.

	Fed Milk Containing 3% Fat.		Fed Milk Containing 5.6% Fat.	
	No. 1.	No. 2.	No. 3.	No. 6.
	Lbs.	Lbs.	Lbs.	Lbs.
Wt. of lambs at beginning of trial, -	19.7	16.6	16.8	16.8
Wt. of lambs at 20 days, - - -	25.3	21.8	22.1	22.1
Wt. of lambs at 40 days, - - -	31.0	27.0	26.5	26.0
Wt. of lambs at 60 days, - - -	39.0	35.0	34.0	30.0
Total gain in weight per pair, - -	37.7		30.4	
Milk consumed, per pair, - - -	285.		221.	
Hay consumed, per pair, - - -	36.		36.	
Solids for one pound of gain, - -	1.08		1.37	

Table 44 shows the gains, the hay and milk consumed, and the solids in milk for one pound of gain with lambs.

In this trial each pair of lambs received the same amount of milk solids per day. The small gains of the pair receiving the richer milk may be attributed to lack of appetite. The solids required for one pound of gain were 1.08 pounds with milk poor in fat and 1.37 pounds with the milk rich in fat.

Composition of milk fed.—The amounts of total solids in the milk were estimated by formula from lactometer readings and the Babcock fat tests. Samples were saved also for chemical analyses, but the determinations were not made until the samples had undergone some change, affecting, no doubt, the milk sugar. Accepting the analyses as reported, the distribution of ingredients was not materially different from that in normal mixed milk containing corresponding amounts of total solids.

TABLE 45.

Milk solids required for one pound of gain, average of 16 animals.

	Milk Poor in Fat.	Milk Rich in Fat.
	Lbs.	Lbs.
Average of 2 pair calves, 45 days, - - - - -	1.03	1.18
Average of first trial, 2 pair pigs, 40 days, - - -	1.36	1.77
Average of second trial, 2 pair pigs, 30 days, - -	1.40	1.56
Average of 2 pair lambs, 60 days, - - - - -	1.08	1.37
Average of 8 pair animals, - - - - -	1.22	1.47

The figures in the above table should not be regarded as a comparison of the assimilative capacity of different classes of animals. The table shows in each case that the pair receiving the milk poor in fat required less food for a pound of gain than the pair receiving the milk rich in fat; and the average for the former was 20 per cent. less.

Size of fat globules in milk fed.—The size of the fat globules was determined at the end of the last experiment. Milk from the same cows and at about the same period of lactation was used in the other experiments. The average diameter of the fat globules in the poor milk, compared with the average diameter of the fat globules in the rich milk, was as 2. to 3.5, and their volume as 1 to 5.

Size of fat globules in human and cows' milk.—The size of fat globules in cows' milk is given by Wing as 1/1500 to 1/25000 of an inch in diameter. The size of fat globules in human milk, according to Foster (p. 613), is from 1/5000 to 1/12500 of an inch in diameter. The largest fat globules in cows' milk are therefore much larger than the largest in human milk.

Results and conclusions.—These experiments were made with young animals, in which, no doubt, the digestive fluids were not in full and active operation.

To produce one pound of gain in live weight in these young animals, more total solids were required with the milk rich in butter fat than with the milk poor in butter fat.

Later in the trials with pigs fed rich milk ad libitum, serious digestive disturbances were noticed.

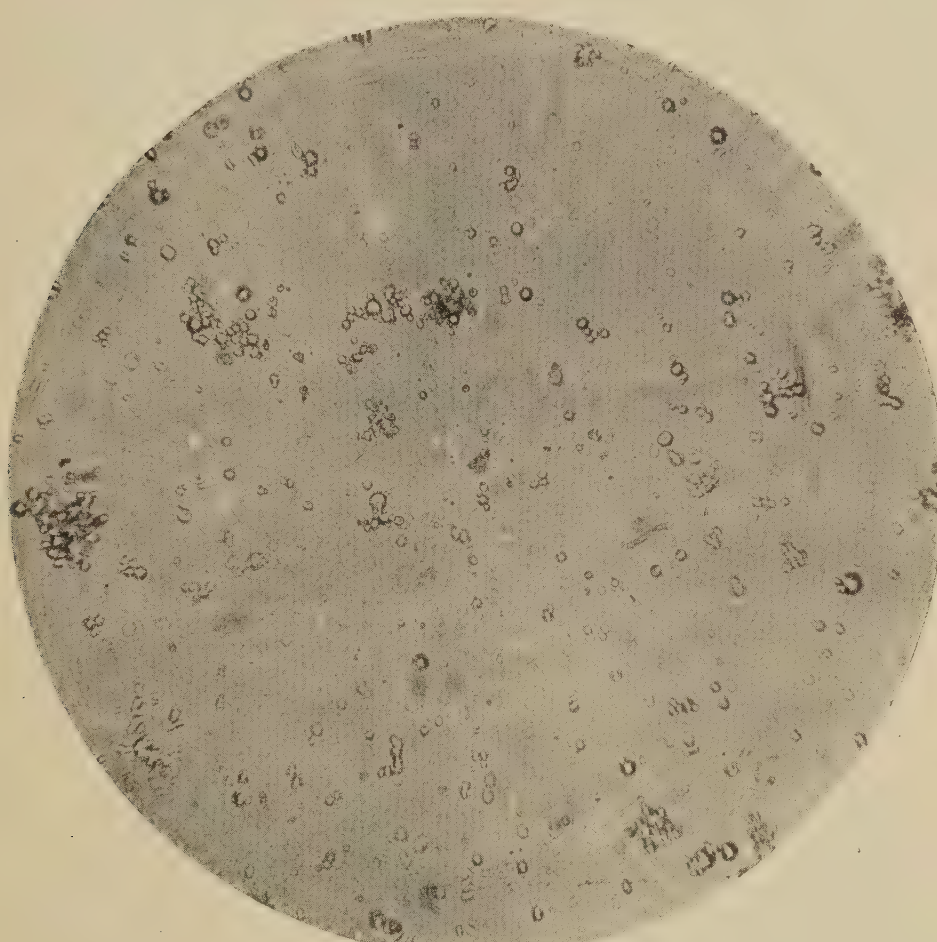


Fig. 12. Fat globules in human milk.

The failure of a pound of milk solids in rich milk to make equal or better gains than a pound of solids in the poor milk was not due apparently to lack of nitrogenous material, but rather to the excess of fat or to the *character* of the fat.

Larger fat globules were found in the richer milk, and this fact, in connection with the digestive disturbances, would seem to indicate the reason for the larger gains from a pound of solids with the poorer milk.

Fat globules in human milk are smaller than the fat globules in cows' milk. If it is safe to reason by analogy from the brute to the human, then whole milk containing a low per cent. of fat would seem to be better suited for infant feeding than whole milk high in per cent. of fat.

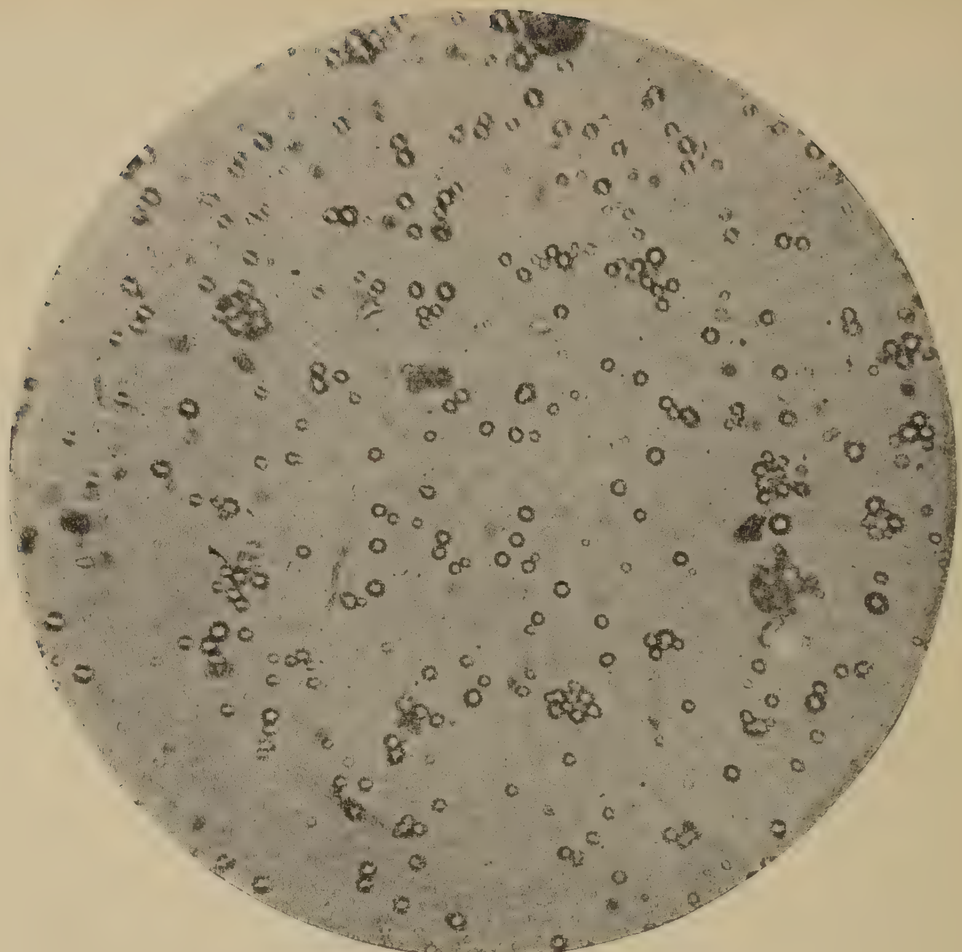


Fig. 13. Fat globules in Holstein milk.

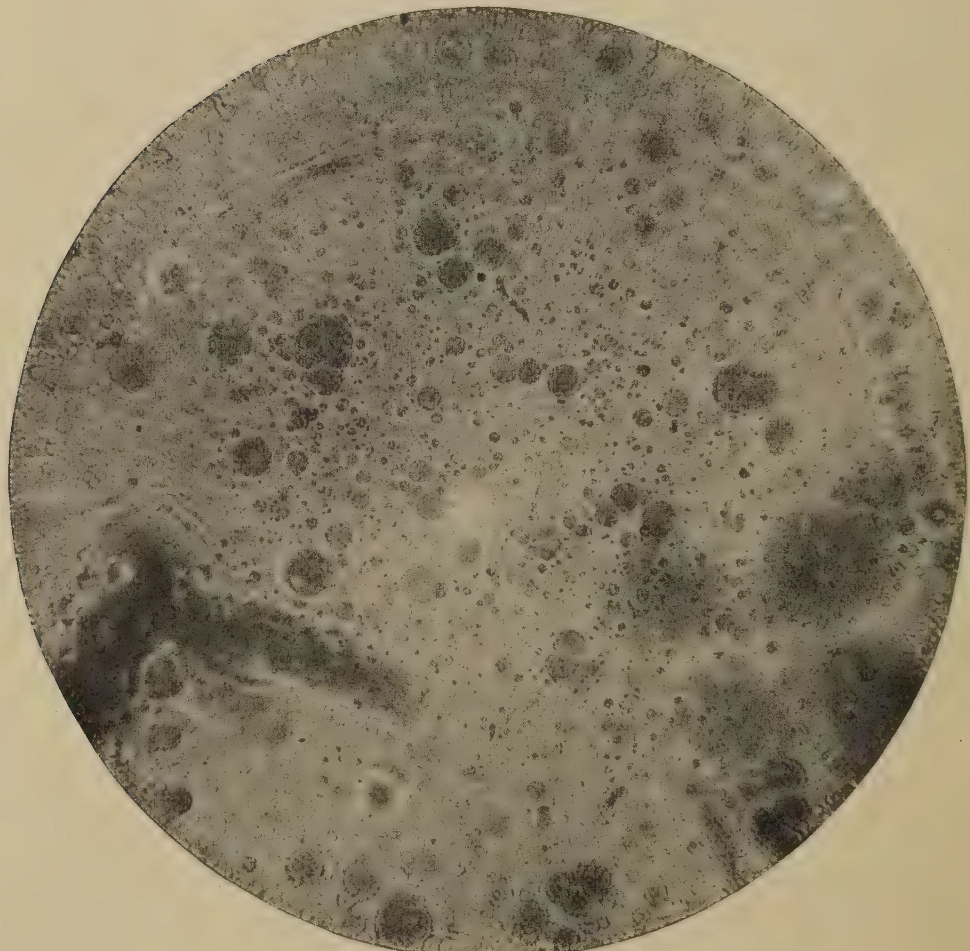


Fig. 14. Fat globules in Jersey milk.

PROTECTING COWS FROM FLIES.

BY C. L. BEACH AND A. B. CLARK.

Midsummer is known as "fly time" in the dairyman's calendar. The marked falling off in the milk flow of the dairy cows at this season of the year is looked upon as unavoidable, and is attributed by many to the worry of the stock by flies. The failure to provide an abundance of succulent forage to supplement the parched pastures seems a trifling contributory cause of the lessened milk secretion, compared with the activity of the pesky, ubiquitous fly, especially at milking time.

The flies that are most numerous about cattle in this locality are of two varieties, and are known by their common names of the Stable Fly and the Horn Fly.

The *Stable Fly* resembles the house fly very much in appearance, but differs in having the mouth parts fitted for piercing the skin and sucking the blood of animals. The eggs of the stable fly are usually laid in horse manure, the female laying from 125 to 150 in a season. The period of development from egg to adult fly is about fifteen days.

The *Horn Fly* is a new pest, and was first noticed in this country about 1886. The first appearance of this fly was the cause of considerable alarm among the cattle men, and the experiment stations of the various states were appealed to for information in regard to the origin and life history of this insect and for suggestions as to agencies for repelling it. From various sources the following information is gleaned in regard to the habits and characteristics of the horn fly.

The horn fly is a small, gray fly, very much like the house fly, but smaller, measuring about three-sixteenths of an inch in length. They have the strange habit of settling in great numbers about the base of the horn, which they sometimes completely cover, a habit which gives them their common name. They confine their attention to cattle. They burrow in the hair about the shoulder, the roots of the tail, and other

portions of the body where they are not easily dislodged. The injury done by the horn fly is by stinging, much like the mosquito. By means of a fine lancet they pierce the skin, and suck the blood through the tube or sheath. A small amount of irritating saliva is secreted in the operation, which causes congestion around the wound and probably more pain than the piercing. They appear in swarms, and feed with the wings spread. The eggs are placed in the fresh droppings of the cow, and the larvæ can exist only in the soft, almost liquid manure. The life cycle

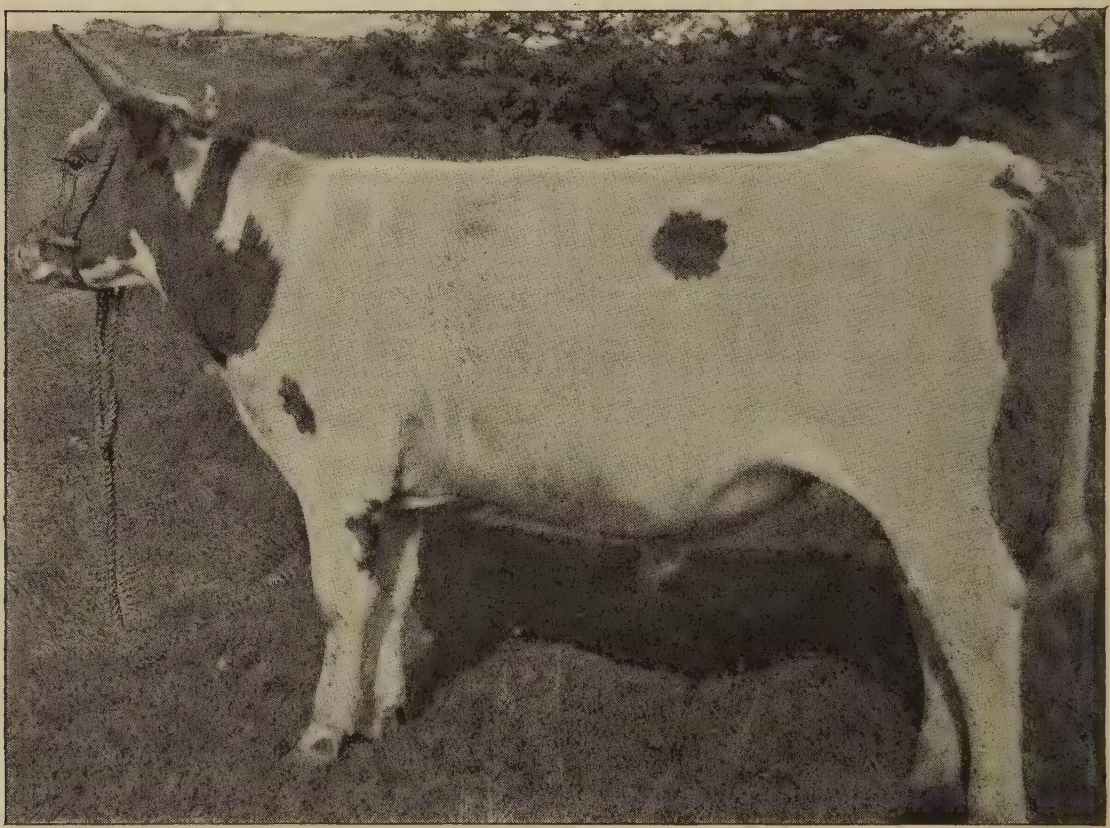


Fig. 15. Showing bull covered with horn flies.

from egg to fly is about fifteen days. Some individual animals suffer more than others, and dark colored animals more than light colored. These flies follow cattle to the barn at night, and remain with them all the time.

Remedies:—In response to a demand for the relief of stock from the annoyance of flies, various remedies have been suggested:

1. A machine for catching flies from the backs of animals as they entered the stables.
2. Destruction of larvæ in the droppings by application of lime or the immediate spreading and drying of the same.

3. Application of tobacco powder and X. O. dust to destroy the flies.
4. The application of repellants:
   (*a*) Ten to fifteen per cent. kerosene in water.
   (*b*) Fish oil with small admixture of carbolic acid.
   (*c*) Cotton seed oil two parts and pine tar one part.
   (*d*) Proprietary remedies: Shoo-Fly, Stop Fly, Eureka, Flyene, Sure Thing, Cow Ease, Cattle Comfort, Norwood Sanitary Fluid, Ely Fly Chaser, Ripley's Fly Remover, Cypher's Anti-fly Pest, Victor.

Efficiency of Proprietary Remedies.—In the Wisconsin report for 1899, Carlyle reports an experiment in protecting cows from flies. "The horn fly is much more easily guarded against than the stable fly, since it may be kept away by spraying the cows with the various substances on the market for this purpose. With the stable fly, however, it is different. None of the quack nostrums on the market nor any that we could compound seemed to have any virtue after they had been applied."

The Massachusetts Hatch Experiment Station reports trials with ten of these so-called fly removers. When applied to horses with an Aspinwall sprayer, four of these proved to be "quite satisfactory, and four were less satisfactory, and two were unsatisfactory." In the four that were reported as quite satisfactory with horses, Shoo-Fly and Ely Fly Chaser, when applied to cows night and morning with a brush, proved "fairly effective in keeping off small flies, but not the large house fly." Eureka was reported as "fairly satisfactory—weather cool, and trial consequently not as thorough as others." Flyene was reported as being "very effective, keeping the flies off for a long time." (Eureka and Flyene applied with a sponge.)

During the past two years we have used one of the proprietary fly removers on the College herd. The repellant used is advertised as the original stock protector, and has been upon the market since 1885. It is claimed by the manufacturers to effect a saving, during the 120 days of fly time, of $14 in cash per cow, to say nothing of the milker's comfort and of humanity.

In 1902 the herd was divided into two divisions, care being taken to have the groups similar as to age, breed, period of lactation, and milk and butter fat production. The grain and silage ration was not changed during the trial, but there was a gradual drying up of the pasture. Each cow in both groups

was sprayed with the fly remover every morning of alternate weeks during the trial. The treatment of the two groups was the same except as to the periods in which they were sprayed, which were alternated.

TABLE 46.

Milk Flow, Group I.

NAME OF COW.	July 16–22. Sprayed	July 23–29. Not Sprayed	July 30 to Aug. 5 Sprayed	Aug. 6-12 Not Sprayed	Aug. 13-19. Sprayed	Average 3 Weeks Sprayed	Average 2 Weeks Not Sprayed
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
Sully, - - -	141.6	142.4	142.1	143.6	131.4	138.3	143.0
Cynda, - -	120.1	134.0	127.5	124.4	127.3	124.9	129.2
Bell, - - -	94.7	93.1	86.8	84.3	79.2	86.9	88.7
Molly, - -	128.5	111.1	114.4	115.5	104.9	115.9	113.3
Nellie, - -	121.1	119.7	114.0	116.6	117.9	117.6	118.1
Mina, - - -	201.1	198.1	189.6	178.2	173.4	188.0	188.1
Lena, - - -	93.1	87.3	77.1	79.0	80.8	83.6	83.1
Rob B., - -	48.2	40.9	34.5	27.6	21.4	34.7	34.2
	948.4	926.6	886.0	869.2	836.3	889.9	897.7

TABLE 47.

Milk Flow, Group II.

NAME OF COW.	July 16–22. Not Sprayed	July 23–29. Sprayed	July 30 to Aug. 5 Not Sprayed	Aug. 6-12 Sprayed	Aug. 13-19. Not Sprayed	Average 3 Weeks Not Sprayed	Average 2 Weeks Sprayed
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
R. B. 2nd, - -	136.6	127.7	126.4	126.0	121.7	128.2	126.8
Perhaps, - -	66.8	52.1	45.2	35.7	30.0	47.3	43.9
Rose 2nd, - -	37.1	27.7	23.8	20.3	18.5	26.5	24.0
Petite, - -	226.2	200.8	205.3	201.6	194.5	208.6	201.2
Jane S., - -	159.8	157.5	150.4	146.7	135.2	148.5	152.1
Bess, - - -	127.6	122.6	121.2	125.3	125.9	124.9	123.9
Copper A., - -	96.2	98.1	99.7	96.7	91.2	95.7	97.4
Barberry Bell, -	83.8	74.5	62.8	64.9	60.4	69.0	69.7
	934.1	861.0	834.8	817.2	777.4	848.7	839.0

It will be seen from Tables 46 and 47 that there was no gain in milk production from spraying.

TABLE 48.

Butter Fat Production, Group I.

NAME OF COW.	July 16–22. Sprayed	July 23–39. Not Sprayed	July 30 to Aug. 5 Sprayed	Aug. 6–12 Not Sprayed	Aug. 13–19. Sprayed	Average 3 weeks Sprayed	Average 2 weeks Not Sprayed
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs	Lbs.
Sully, - - -	6.94	6.55	6.39	7.04	6.24	6.52	6.79
Cynda, - -	5.16	5.90	5.42	5.06	5.92	5.50	5.48
Bell, - - -	5.73	5.73	4.95	5.35	4.65	5.11	5.54
Molly, - -	6.10	5.33	6.18	5.94	5.77	6.02	5.63
Nellie, - -	5.93	5.99	5.59	5.89	5.78	5.76	5.94
Mina, - - -	8.35	8.62	8.15	7.84	7.46	7.98	8.23
Lena, - - -	5.49	5.11	4.59	4.70	5.17	5.08	4.90
Rob B., - -	3.18	2.76	2.21	1.79	1.66	2.35	2.27
	46.88	45.99	43.48	43.61	42.65	44.32	44.78

TABLE 49.

Butter Fat Production, Group II.

NAME OF COW.	July 16–22. Not Sprayed	July 23–29. Sprayed	July 30 to Aug. 5 Not Sprayed	Aug. 6–12. Sprayed	Aug. 13–19. Not Sprayed	Average 3 weeks Not Sprayed	Average 2 weeks Sprayed
	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
R. B., 2nd, - -	6.76	6.51	6.32	6.87	6.23	6.43	6.69
Perhaps, - -	3.67	2.76	2.30	1.91	1.59	2.52	2.33
Rose, 2nd, - -	1.82	1.33	1.19	1.06	1.00	1.33	1.19
Petite, - -	9.50	8.23	8.62	8.96	8.65	8.92	8.59
Jane S., - -	6.95	6.73	6.32	6.55	6.02	6.43	6.64
Bess, - - -	6.51	6.62	6.48	6.82	7.30	6.76	6.72
Copper A., - -	5.87	5.89	5.93	5.80	5.75	5.85	5.84
Barberry B., -	3.39	3.28	2.70	2.86	2.72	2.93	3.07
	44.47	41.35	39.86	40.83	39.26	41.17	41.07

Tables 48 and 49 show no gain in butter fat production from spraying.

Table 46, columns 6 and 7, shows that the average milk flow for the first, third, and fifth weeks, when the cows were sprayed, was 889.9 pounds; and the average for the second and fourth weeks, when not sprayed, was 897.7 pounds of milk, or a loss of 7.8 pounds when sprayed.

Table 47 shows that Group II. gave in the first, third, and fifth weeks, when not sprayed, an average of 848.7 pounds of milk, and when sprayed gave 839.0 pounds, or a loss of 9.7 pounds.

Tables 48 and 49 show that with Group I. the fat production was .46 pound less and with Group II., .1 pound less when sprayed.

TABLE 50.

Weekly Milk Shrinkage of Groups I. and II.

Group I.				Group II.		
Time.	Treatment.	Amt. of Milk.	Shrinkage from previous week.	Amt. of Milk.	Shrinkage from previous week.	Treatment.
		Lbs.	Lbs.	Lbs.	Lbs.	
July 16-22, -	Sprayed, -	948.4	—	934.1	—	Not Sprayed.
July 23-29, -	Not Sprayed,	926.6	21.8	861.0	73.1	Sprayed.
July 30-Aug. 5,	Sprayed, -	886.0	40.6	834.8	26.2	Not Sprayed.
Aug. 6-12, -	Not Sprayed,	869.2	16.8	817.2	17.6	Sprayed.
Aug. 13-19, -	Sprayed, -	836.3	32.9	777.4	39.8	Not Sprayed.

The same brand of "fly remover" was tested again in 1903. The herd was divided into two divisions as before, and the plan of the experiment was the same, except that the cows were sprayed for a period of two weeks. In the first period Group I. was sprayed, and Group II. was not. In the second period Group II. was sprayed, and Group I. was not. In Period III. the treatment was the same as in the first period.

The difference in the individuality of the milkers was eliminated by having each one milk the same number of cows in each group. The repellant was applied thoroughly once a day to all parts of the animal. The hair of the animals became more or less gummy. The milk on several occasions had a peculiar odor, which was attributed to the ointment. The milk flow and the butter fat production of the second week of each period are taken for comparison. It was thought possible that in the previous year the week periods were too short, and that the effects of spraying extended over into the succeeding week,

when the cows were not sprayed. The ointment this year was efficient as a fly remover. The difference in the number of flies on the individuals of the different groups was quite noticeable; those that were not sprayed for two weeks would at times be covered with a swarm of flies, and the individuals of the other group would be comparatively free. The number of flies attracted to different individuals of the herd varied greatly, but the annoyance, if there was any, was not recorded in the milk

TABLE 51.

Milk Flow, Group I. 1903.

NAME OF COW.	July 21–27. Sprayed.	Aug. 4–10. Not Sprayed.	Aug. 18–24. Sprayed.	Ave. of 2nd week of 1st and 3d period. Sprayed.	2nd week of 2nd period. Not Sprayed.
L. Naomi, - -	125.4	117.1	106.9	116.1	117.1
Molly, 2nd, -	105.9	97.1	93.4	99.6	97.1
Molly, - -	129.6	120.2	109.1	119.3	120.2
Stelline, - -	62.5	50.3	41.6	52.0	50.3
Fay M., - -	121.3	94.5	80.8	101.0	94.5
Petite, - -	88.7	74.3	57.2	72.9	74.3
Ethel's Fancy, -	81.7	73.9	72.1	76.9	73.9
Mina, - -	161.8	156.6	147.9	154.8	156.6
Eurotas, - -	122.9	120.1	115.1	119.0	120.1
	999.8	904.1	824.1	911.6	904.1

TABLE 52.

Milk Flow, Group II.

NAME OF COW.	July 21–27. Not Sprayed.	Aug. 4–10. Sprayed.	Aug. 18–24. Not Sprayed.	Ave. of 2nd week of 1st and 3rd period. Not Sprayed.	2nd week of 2nd period. Sprayed.
Naomi's B., -	86.3	72.8	73.5	79.9	72.8
Barberry B., -	100.3	88.4	75.8	80.0	88.4
Jane S., - -	154.1	138.0	147.9	151.0	138.0
Pietertje, - -	163.4	139.6	120.1	141.7	139.6
Bell, - - -	122.9	118.0	109.3	116.1	118.0
Copper A., -	112.5	108.5	99.8	106.1	108.5
Lady D., - -	58.5	48.6	38.9	48.7	48.6
R. B., 2nd, -	91.3	82.2	86.9	89.1	82.2
Brownie, - -	83.9	78.5	76.7	80.3	78.5
	973.2	874.6	828.9	900.9	874.6

flow or butter fat production. Cows are often covered with a swarm of flies, and yet apparently suffer little annoyance. It has occurred to the writer that the fly may often feed upon the liquid excretions of the skin, and act as a scavenger rather than as a blood-thirsty villain.

Table 51 shows the milk flow of Group I. for the second week of each period. The average for the two periods when sprayed was 911.6 pounds of milk, and 904.1 when not sprayed.

Table 52 shows that Group II. gave 900.9 pounds on an average for the two periods when not sprayed, and 874.6 when sprayed, or 26.3 pounds less when sprayed.

TABLE 53.

Butter Fat Yield of Group I. 1903.

NAME OF COW.	Sprayed.	Not Sprayed.	Sprayed.	Average of 1st and 3d periods. Sprayed.	2nd period. Not Sprayed.
L. Naomi, - -	5.41	5.15	5.02	5.21	5.15
Molly 2nd, - -	4.87	4.47	4.20	4.53	4.47
Molly, - -	6.48	6.25	5.78	6.13	6.25
Stelline, - -	2.62	2.01	1.75	2.18	2.01
Fay M., - -	3.63	3.02	2.59	3.11	3.02
Petite, - -	5.67	4.01	3.09	4.38	4.01
Ethel's Fancy, -	4.82	4.14	4.14	4.48	4.14
Mina, - - -	6.79	6.89	5.91	6.35	6.89
Eurotas, - -	5.53	5.52	5.76	5.64	5.52
	45.82	41.46	38.24	42.01	41.46

TABLE 54.

Butter Fat Yield of Group II.

NAME OF COW.	Not Sprayed.	Sprayed.	Not Sprayed.	Average of 1st and 3d periods. Not Sprayed.	2nd period. Sprayed.
Naomi B, - -	4.05	3.49	3.45	3.75	3.49
Barberry B, -	4.21	4.06	3.41	3.81	4.06
Jane S, - -	6.62	6.34	6.50	6.56	6.34
Pietertje, - -	6.53	5.86	5.28	5.90	5.86
Bell, - - -	6.97	7.31	6.77	6.87	7.31
Copper A., - -	6.52	6.29	6.09	6.30	6.29
Lady D., - -	2.22	1.65	1.44	1.83	1.65
R. B. 2nd, - -	4.84	5.26	5.82	5.33	5.26
Brownie, - -	4.70	4.87	4.60	4.65	4.87
	46.66	45.13	43.36	45.00	45.13

Tables 53 and 54 show that Group I. gave .45 pounds more butter fat when not sprayed, and Group II. .13 pound more when sprayed.

TABLE 55.

Weekly Milk Shrinkage of Groups I. and II. 1903.

	Group I.			Group II.		
	Amt. of Milk.	Shrinkage from previous Period.	Treatment.	Treatment.	Amt. of Milk.	Shrinkage from previous Period.
	Lbs.	Lbs.			Lbs.	Lbs.
1st Period, -	999.8	—	Sprayed, -	Not Sprayed,	973.2	—
2nd Period, -	904.1	95.7	Not Sprayed,	Sprayed, -	874.6	98.6
3rd Period, -	824.1	80.0	Sprayed, -	Not Sprayed,	828.9	45.7

Table 55 shows that Group I. made a shrinkage of 95.7 pounds when not sprayed and 80. when sprayed, and that Group II. made a shrinkage of 98.6 when sprayed and 45.7 when not sprayed.

Our experience during the past two years would indicate that the annoyance to dairy cows by flies has been over-estimated, and that the benefits from the use of proprietary fly removers have been exaggerated.

This conclusion is in harmony with an experiment of Carlyle of Wisconsin Station, in which one-half of the herd was protected from the annoyance of flies by stabling during the day time. The remainder of the herd was confined in a paddock during the day. The trial lasted four weeks with the following results:

TABLE 56.

	Cows in Stable.	Cows in Paddock.
Pounds of green feed eaten in four weeks, - -	5747	4912
Average decrease in live weight, - - - -	30	11
Decrease in milk flow of seven cows in two weeks, -	56.7	40.4
Decrease in butter fat production of seven cows in two weeks, - - - - - - - - - -	.81	2.16

The cows protected from flies by being stabled ate in four weeks 835 pounds more of green feed, and lost 133 pounds more in flesh than those confined during the day in the paddock and exposed to the annoyance of flies. In two weeks the former decreased 16.3 pounds more in the milk flow and 1.35 pounds less in the butter fat production.

CONCLUSIONS.

1. The annoyance of cows by flies seems to be over-estimated.

2. Certain proprietary ointments, known as "fly removers," will protect the animal to a greater or less extent, but their use has little or no effect on the milk or butter fat secretion.

YIELD OF FRONT AND REAR UDDER OF THE COW.

REPORTED BY C. L. BEACH AND A. B. CLARK.

Table 57 shows the quality and the percentage of the total yield of each quarter of the udder. The record includes the yield of two milkings from each of fifteen cows. The milk was drawn in the ordinary manner, except that four three-quart pails were used, and in this way the milk from each

TABLE 57.

No. of Cow.	Time of Milking.	Total Milk Yielded.	Per Cent. of Total Milk Yield, Front Udder.		Per Cent. of Total Milk Yield, Rear Udder.		Babcock Test.			
							Front Udder.		Rear Udder.	
			Right quarter.	Left quarter.	Right quarter.	Left quarter.	Right quarter.	Left quarter.	Right quarter.	Left quarter.
		Lbs.					%	%	%	%
1	P. M.	5.3	17.0	22.7	18.8	41.5	9.0	9.2	8.3	8.2
1	A. M.	4.5	17.8	22.2	17.8	42.2	6.2	6.2	6.6	6.2
2	P. M.	12.9	24.0	20.1	27.9	27.9	4.1	4.0	4.0	4.2
2	A. M.	15.6	23.1	21.1	28.8	27.0	4.0	4.0	4.0	3.9
3	P. M.	12.2	19.6	23.8	27.0	29.5	6.0	6.0	4.8	5.0
3	A. M.	11.7	17.1	26.5	28.2	28.2	4.4	4.0	3.6	3.8
4	P. M.	5.1	21.5	19.6	31.4	27.4	5.6	5.6	6.2	6.1
4	A. M.	3.9	20.5	15.4	36.0	28.2	6.2	6.2	6.2	6.0
5	P. M.	14.8	19.0	23.0	29.0	29.0	4.7	4.0	5.0	5.4
5	A. M.	18.6	20.4	21.5	29.5	28.5	4.1	3.4	3.6	5.0
6	P. M.	2.7	18.5	18.5	33.3	29.6	4.9	4.9	5.4	5.2
6	A. M.	3.2	18.7	18.7	31.3	31.3	4.4	4.4	4.8	4.6
7	P. M.	10.4	21.1	18.2	28.8	31.8	6.5	6.7	6.1	6.4
7	A. M.	12.6	20.7	16.7	30.1	32.4	6.0	7.0	5.8	5.2
8	P. M.	7.3	21.9	21.9	35.6	20.5	6.5	6.7	6.1	6.4
8	A. M.	8.5	22.3	25.8	31.8	20.0	6.0	7.0	5.8	6.2
9	P. M.	6.9	42.1	15.9	21.7	20.3	6.8	6.5	6.4	6.4
9	A. M.	7.0	42.8	15.6	17.2	24.3	5.8	5.8	5.4	5.8
10	P. M.	5.8	26.0	20.7	27.2	26.0	5.4	5.4	6.1	5.8
10	A. M.	8.8	21.6	16.0	28.4	34.0	4.4	4.0	4.4	4.4
11	P. M.	9.7	17.5	16.5	33.0	33.0	4.5	5.4	5.0	5.2
11	A. M.	10.6	17.0	15.0	34.0	34.0	4.9	5.1	5.0	5.0
12	P. M.	8.3	25.3	24.1	24.1	26.5	4.5	4.8	5.7	5.4
12	A. M.	9.7	25.7	24.7	22.7	26.8	3.7	4.1	4.2	4.1
13	P. M.	11.0	20.0	18.2	25.4	36.3	4.5	4.8	4.4	5.2
13	A. M.	11.6	19.0	21.5	27.6	31.9	4.2	4.2	4.2	4.3
14	P. M.	7.0	17.1	22.8	31.4	28.6	6.6	6.5	6.6	6.4
14	A. M.	7.9	22.7	20.3	29.0	28.0	6.8	7.2	6.5	7.0
15	P. M.	14.3	21.0	19.0	30.7	29.3	4.8	4.3	4.8	4.6
15	A. M.	15.1	20.5	19.8	30.5	29.1	4.3	3.8	4.0	4.2
Average,		9.43	22.1	20.2	28.3	29.4	5.35	5.34	5.35	5.41

quarter was drawn into a separate pail, and was weighed and tested. The average of the thirty milkings shows that 42.3 per cent. of the total yield of milk was secreted by the front udder, and 57.7 per cent. by the rear udder. The average quality of the milk from each quarter was the same.

Table 58 shows the quality and yield of milk from each quarter for one milking each in a herd of fifteen cows. In this trial the front udder yielded 38.8 per cent., and the rear udder 61.2 per cent. of the total yield. The quality of the milk from each quarter was again practically the same.

The average of the two trials shows that the udder of the cow is not balanced, but that about two-fifths (40.6 per cent.) of the milk is secreted in front, and three-fifths (59.4 per cent.) in the rear udder.

TABLE 58.

No. of Cow.	Total Milk Yield.	Per Cent. of Total Milk Yield, Front Udder.		Per Cent. of Total Milk Yield, Rear Udder.		Babcock Test.			
						Front Udder		Rear Udder.	
		Right quarter.	Left quarter.	Right quarter.	Left quarter.	Right quarter.	Left quarter.	Right quarter.	Left quarter.
	Lbs.					%	%	%	%
1 - -	11.2	25.0	18.8	25.0	31.2	6.4	7.2	7.4	6.2
2 - -	12.7	21.3	23.6	31.5	23.6	4.2	4.0	4.2	4.4
3 - -	11.0	17.3	17.3	30.9	34.5	4.6	4.2	4.0	4.6
4 - -	10.4	20.2	15.3	29.9	34.6	4.4	4.4	5.6	5.6
7 - -	7.5	17.4	20.0	25.3	37.3	4.4	3.8	3.6	3.2
8 - -	10.2	19.5	24.5	33.3	22.7	5.1	5.2	5.4	5.2
16 - -	10.8	16.7	13.9	32.4	37.0	4.2	4.4	4.6	4.6
17 - -	6.0	18.3	23.3	21.7	36.7	6.3	4.6	5.0	4.8
18 - -	15.8	25.3	22.2	27.2	25.3	4.0	4.4	4.6	4.6
19 - -	12.8	11.0	21.1	31.2	36.7	5.6	4.6	5.3	5.2
20 - -	6.1	19.7	21.3	29.5	29.5	5.4	6.0	6.0	6.0
21 - -	10.3	19.4	24.2	28.2	28.2	3.4	4.2	3.4	3.6
22 - -	10.3	11.7	17.5	38.8	32.0	2.8	3.0	2.6	2.4
23 - -	20.5	19.6	24.4	25.8	30.2	3.1	3.6	3.0	3.5
24 - -	5.9	11.9	20.3	32.2	35.6	4.8	4.8	5.0	4.4
Average, -	10.7	18.3	20.5	29.5	31.7	4.58	4.56	4.55	4.54

Development of udder and capacity for secretion.—A good udder should extend well forward and up behind and from side to side. The udder should be large, but not at the expense of fatty or fleshy tissue. The capacity for secretion is

dependent not only upon the size of the udder, but also upon the amount of blood passing through the udder and upon the nervous energy of the animal.

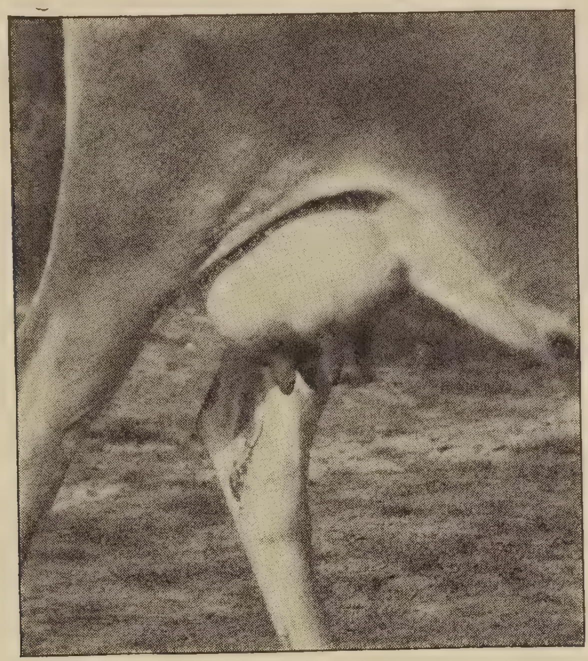


Fig. 16. Poor front udder.

Cuts 16 and 17 show the front and rear udder of the cow No. 16 (see table 58), 30.6 per cent. of milk yielded in front udder and 69.4 per cent. in rear udder.

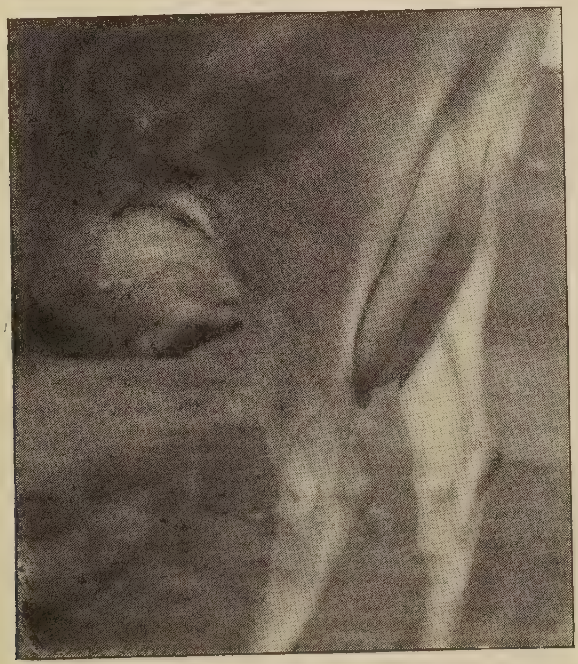


Fig. 17. Good rear udder.

The observations recorded are too few in number to justify a comparison of milk yield with types or styles of udders. A physical examination, however, of the quarters of the udder whose yields are below the average will reveal almost without exception a natural deficiency or hardness, indicating an injury.

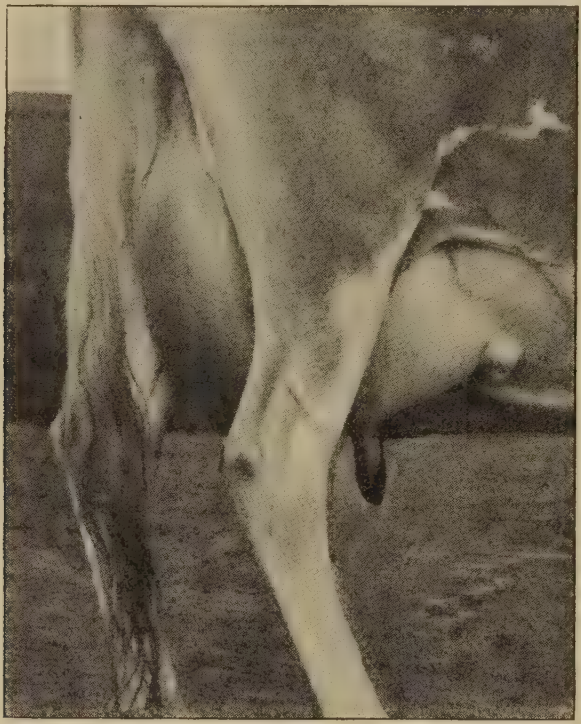


Fig. 18. Exceptionally well developed front udder.

Cut 18 shows front and rear udder of cow No. 18, (Table 58) 47.5 per cent. of milk yielded by front udder and 52.5 per cent. by rear udder.

THE MILK YIELD OF QUARTERS ON SAME SIDE OF UDDER.

REPORTED BY C. L. BEACH.

The udder of the cow consists of two glands, one on each side of the middle line of the body. Each gland consists of two lobes or quarters, each having a teat upon the lower side. The end of the teat is guarded by an involuntary sphincter muscle. Above the teat is the milk cistern, the capacity of which is about half a pint. Small canals, or milk ducts, extend from the cistern to all portions of the udder. These ducts divide and subdivide, gradually growing smaller as they extend upward. At the end of the ducts are small sac-like bodies called acini or ultimate follicles, which are lined with epithelial cells, in which the milk is secreted. The follicles are surrounded with veins, arteries, nerves, and lymphatics, and besides these essentials the udder may contain fatty or fleshy tissue. Fibrous connective tissue extends throughout the udder, and connects it with the body.

The glands and quarters are independent.—The glands on either side of the udder are independent of each other. It is stated by various writers that there is more or less connection between the quarters on the same side of the udder, which renders it possible to draw from the hind teat a part of the milk secreted in the front quarter, and vice versa. From a physiological point of view it is difficult to understand this view of the matter. Dr. Babcock* reports the amount of milk yielded by a cow when milked one teat at a time for four successive milkings. At each milking the teats were milked in different order. Prof. Plumb† reports the yield of four cows when milked in the same manner. If A designate the right fore teat, B the right hind teat, C the left hind teat, and D the left fore teat, then the tables below show the effect of milking one

*Report of Wisconsin Experiment Station, 1889.
†Indiana Bulletin, No. 62.

teat at a time in the manner indicated. Incidentally the yields of the front and rear quarters on the same side when milked in advance of and after each other are obtained.

Referring to Table 59, it is seen that A (right fore) was milked three times in advance of B (right hind) and once afterward. B was milked three times after and once in advance of A. If the quarters on the same side of the udder can draw milk from each other, then either quarter on the same side should give more milk when milked first than when milked last. The table below shows that A gave less milk when milked before B, and B more milk when milked after A. C gave 1.4 per cent. more milk when milked before D, but D gave 1. per cent. more when milked after C.

TABLE 59.

Comparison of Milk Yield of Quarters of the Udder when Milked in Advance of and After Quarters on Same Side.

ORDER OF MILKING.	No. of Times.	Average of 5 Cows, per cent. of Milk Yield.	Difference.
		By A.	
A before B, - - - - -	3	23.4	— .5%
A after B, - - - - -	1	23.9	
		By B.	
B after A, - - - - -	3	27.7	+ .7%
B before A, - - - - -	1	27.0	
		By C.	
C before D, - - - - -	3	26.7	+1.4%
C after D, - - - - -	1	25.3	
		By D.	
D after C, - - - - -	3	23.1	+1.0%
D before C, - - - - -	1	22.1	

The average results from five cows milked in this manner were for the quarter milked first, 25.9 per cent.; second, 26.4 per cent.; third, 24.6 per cent.; and fourth, 23.1 per cent. As the yield from each quarter enters into each average, the difference in percentage must be attributed to the order in which the teats were milked.

TABLE 60.

Showing the Effect of Milking One Teat at a Time.

No. of Cow.	Average of Teat Milked First.	Average of Teat Milked Second.	Average of Teat Milked Third.	Average of Teat Milked Fourth.
	%	%	%	%
First cow, - -	21.9	27.1	25.3	25.6
Second cow, - -	28.7	24.87	23.5	22.9
Third cow, - -	26.55	27.2	25.4	20.8
Fourth cow, - -	25.95	25.5	23.1	25.4
Fifth cow, - -	26.27	27.17	25.7	23.1
	25.87	26.4	24.6	23.1

A STUDY IN MILK SECRETION.

REPORTED BY C. L. BEACH.

The quantity of milk and fat secreted by the cow each day is fairly constant. Variations independent of food consumed do occur, however, and from various causes. The tables below show the increase in the amount of milk and of fat secreted as a result of milking three times per day.

In Periods I. and III. eight cows were milked twice per day, at 5:15 A. M. and 4:45 P. M. During Period II. the same cows were milked three times per day at uneven intervals for five days, an additional milking taking place at 11:00 A. M. Tables 61 and 62 show that the eight cows when milked twice per day gave in six days an average total of 187.6 pounds of milk and 8.56 pounds of fat. As a result of three milkings daily they gave 212.5 pounds of milk and 9.77 pounds of fat. This is an increase of three pounds of milk per day per cow, or 13.6 per cent., and .15 pound of fat, or 14.1 per cent.

TABLE 61.

Average Daily Milk Flow of Eight Cows.

Name of Cow.	Period I. Milked Twice Daily. Pounds.	Period II. Milked Three Times Daily. 5.15 A. M. Pounds.	11 A. M. Pounds.	4.45 P. M. Pounds.	Total Pounds.	Period III Milked Twice Daily. Pounds.
Olive, - -	18.1	10.0	5.3	8.4	23.7	17.7
Holstein, -	25.2	14.1	6.7	10.6	31.4	22.4
Butterfly, -	15.9	8.5	6.3	2.9	17.7	16.1
Dolly D, -	27.3	14.6	6.6	11.0	32.2	25.8
Black, - -	26.3	13.9	7.5	4.9	26.3	27.7
Black II., -	28.1	15.2	9.3	4.3	28.8	27.9
Fairview, -	24.6	15.1	7.7	4.2	27.0	26.6
Stella B, -	22.1	12.8	7.1	5.5	25.4	23.5
Average, -	23.45	13.02	7.06	6.47	26.56	23.46
Total, -	187.6	104.2	104.2	51.8	212.5	187.7

TABLE 62.

Average Daily Fat Yield of Eight Cows.

Name of Cow.	Period I. Milked Twice Daily. Pounds.	Period II. Milked Three Times Daily. 5.15 A. M. Pounds.	11 A. M. Pounds.	4.45 P. M. Pounds.	Total Pounds.	Period III Milked Twice Daily. Pounds.
Olive, - -	1.08	.495	.365	.495	1.355	1.079
Holstein, -	1.056	.479	.335	.498	1.312	1.008
Butterfly, -	.9301	.425	.485	.204	1.114	.911
Dolly D, -	1.173	.511	.330	.473	1.314	1.057
Black, - -	1.209	.514	.495	.211	1.220	1.274
Black II., -	1.264	.547	.671	.219	1.437	1.251
Fairview, -	1.058	.543	.462	.168	1.173	1.223
Stella B, -	.751	.384	.291	.170	.845	.799
Average, -	1.065	.487	.427	.305	1.220	1.075
Total, -	8.523	3.898	3.434	2.438	9.770	8.602

Many theories have been advanced in explanation of the process of milk secretion, but no single theory is entirely satisfactory. There seems to be a causative relationship, however, between the nervous condition of the cow and the action of the gland.

The amount of milk and fat secreted per hour at different times in the twenty-four hours is not the same. Table 63 shows that the amount of milk secreted during the night in Period II. was 1.041 pounds per hour and of fat .039 pound, while the amount secreted per hour up to the noon hour was 1.23 pounds of milk and .074 pound of fat.

Results from milking three times per day.—It may be stated that the shorter the time between milkings, the larger the amount of milk and fat secreted per hour. This extra amount secured may be due in part to the additional manipulation of the udder by the hand of the milker as a result of additional milking, but the nervous condition of the cow is, no doubt, a factor.

In Table 63 is given the amount of milk and fat secreted per cow per hour when the cows were milked twice and three times a day. When milked twice per day, the amount of milk secreted per hour was .977 pound, and when milked three times, 1.10 pounds. When milked twice, the amount of fat

secreted was .0446 pound per hour, and when milked three times, .056 pound. It will be noticed, however, that in the morning, after an interval of 12½ hours, the amount of milk secreted per hour was 1.041; at 11.00 A. M., after an interval of five and three-fourths hours, the amount secreted was 1.23 pounds; and at 4:45 P. M., after an interval of five and three-fourths hours, the amount secreted was 1.12 pounds. Similar variations appear in the secretion of fat. At the noon hour the percentage increase in the hourly secretion of milk and of fat, as compared with the hourly secretion when milked twice per day, was 26 per cent. more milk and 66 per cent. more fat. The percentage increase in the hourly secretion of fat up to the noon hour as compared with the morning hour was 89 per cent. more fat, while the secretion of milk was only 18 per cent. more. This difference is attributed by the writer to the nervous condition of the cow due to the unusual hour of milking. The average Babcock test of the cows at noon during the five days of Period II. was 7.1 per cent., 6 per cent., 6 per cent., 5.8 per cent., and 5.8 per cent.

TABLE 63.

Amount of Milk and Fat Secreted per Hour in Pounds.

	PERIOD I.	PERIOD II. Milked Three Times.				PERIOD III
	Milked Twice.	5.15 A. M.	11 A. M.	4.45 P.M.	Average.	Milked Twice.
Milk, - -	.977	1.041	1.23	1.12	1.10	.977
Fat, - -	.0444	.039	.074	.053	.056	.0448

TEST OF COWS FOR ADVANCED REGISTRATION.

REPORTED BY C. L. BEACH AND F. G. COMINS.

For the purpose of encouraging the breeders of pure bred cattle to ascertain and record the productive capacity of their animals, the Jersey, Guernsey, Ayrshire, and Holstein Cattle Associations have established a system of advanced registration based upon the performance of individuals. Animals that reach a certain standard production of milk or butter fat for a given time are entitled to admission to the advanced registry.

Fig. 19. Butterfly Maid.

The following is a record of the milk and fat produced in seven days by the Jersey cow Butterfly Maid, No. 101,269, A. J. C. C., owned by the Connecticut Agricultural College.

This cow gave in seven days 243.9 pounds of milk and 13.0647 pounds of fat, equivalent to 15.37 pounds of butter. This record is of particular interest because it was made two weeks after an attack of milk fever, which was treated by the injection of oxygen into the udder by our veterinarian, Dr. Lehnert. Butterfly Maid was 11 years and 5 months old, and weighed about 950 pounds. She was fed daily during this trial nine pounds of grain, consisting of four parts bran and one of cotton seed meal, and about 100 pounds of green hay. The cow was milked and cared for during the test by one of our students, Mr. F. G. Comins, and great credit is due the latter for conditioning this cow for the test.

TABLE 64.

Record of Butterfly Maid.

		Pounds of Milk.	Per Cent. of Fat.	Pounds of Fat.
1st Day,	5 A. M.,	11.3	4.3	.4859
	1 P. M.,	10.1	6.3	.6363
	8 P. M.,	9.8	5.9	.5782
2nd Day,		12.3	4.4	.5412
		10.8	5.8	.6264
		10.1	6.5	.6565
3rd Day,		13.4	4.3	.5762
		10.3	5.9	.6077
		10.7	6.1	.6527
4th Day,		13.7	4.0	.5480
		13.0	5.8	.7540
		10.4	6.1	.6344
5th Day,		13.9	4.6	.6364
		12.8	6.4	.8192
		11.5	5.2	.5980
6th Day,		11.9	4.8	.5712
		11.0	6.2	.6820
		10.2	5.9	.6018
7th Day,	5 A. M.,	13.2	4.3	.5676
	5 P. M.,	14.6	6.3	.9198
	8 P. M.,	7.9	5.8	.4582
Totals,		243.9	—	13.0647

TEST OF ROBIN BUTTERFLY.

[Property of Connecticut Agricultural College.]

Fig. 20 is from a photograph of the Jersey cow Robin Butterfly, No. 146,899. This cow is a daughter of Butterfly Maid and was six years old at the beginning of the test reported below.

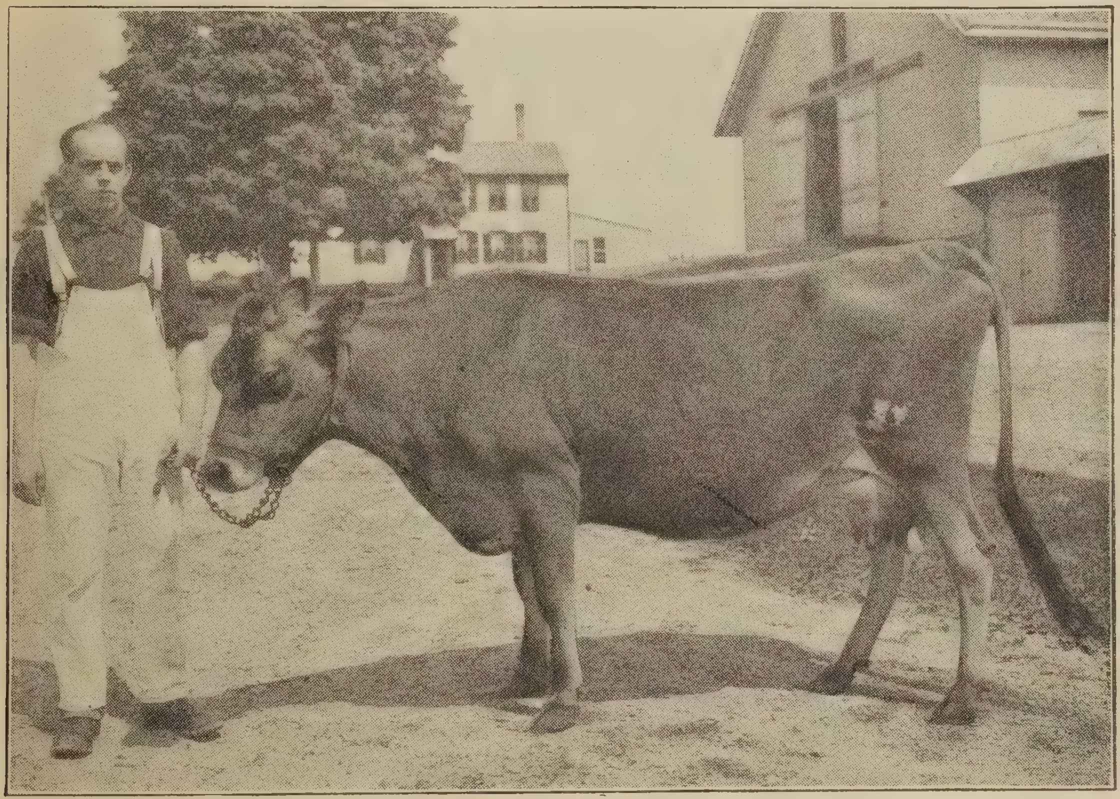


Fig. 20. Robin Butterfly.

The record below shows that Robin Butterfly gave in one year 7,000 pounds of milk and 463.3 pounds of butter fat, equivalent to 540.5 pounds of butter. This record has been accepted by the American Jersey Cattle Club and will be recorded and published by them as a private Babcock fat estimate.

TABLE 65.

Record of Robin Butterfly.

Month After Calving.	Pounds Milk.	Babcock Test.	Pounds Butter Fat.
1st, - - - - - - -	666.1	5.9	39.3
2nd, - - - - - - -	636.8	6.5	41.4
3rd, - - - - - - -	553.9	7.2	39.9
4th, - - - - - - -	543.0	7.1	38.6
5th, - - - - - - -	537.2	6.6	35.4
6th, - - - - - - -	480.6	6.0	28.8
7th, - - - - - - -	406.1	7.6	30.9
8th, - - - - - - -	534.2	7.3	39.0
9th, - - - - - - -	719.0	6.0	43.1
10th, - - - - - - -	644.0	6.4	41.2
11th, - - - - - - -	666.4	6.4	42.6
12th, - - - - - - -	611.1	7.0	42.8
	6998.4	6.6	463.0

TEST OF LILLY EUROTAS, 2ND.

[PROPERTY OF CONNECTICUT AGRICULTURAL COLLEGE.]

Fig. 21 is from a photograph of the Guernsey heifer Lilly Eurotas, 2nd, No. 14,131. The record below is for one year and commenced when the cow was about three years and six months of age.

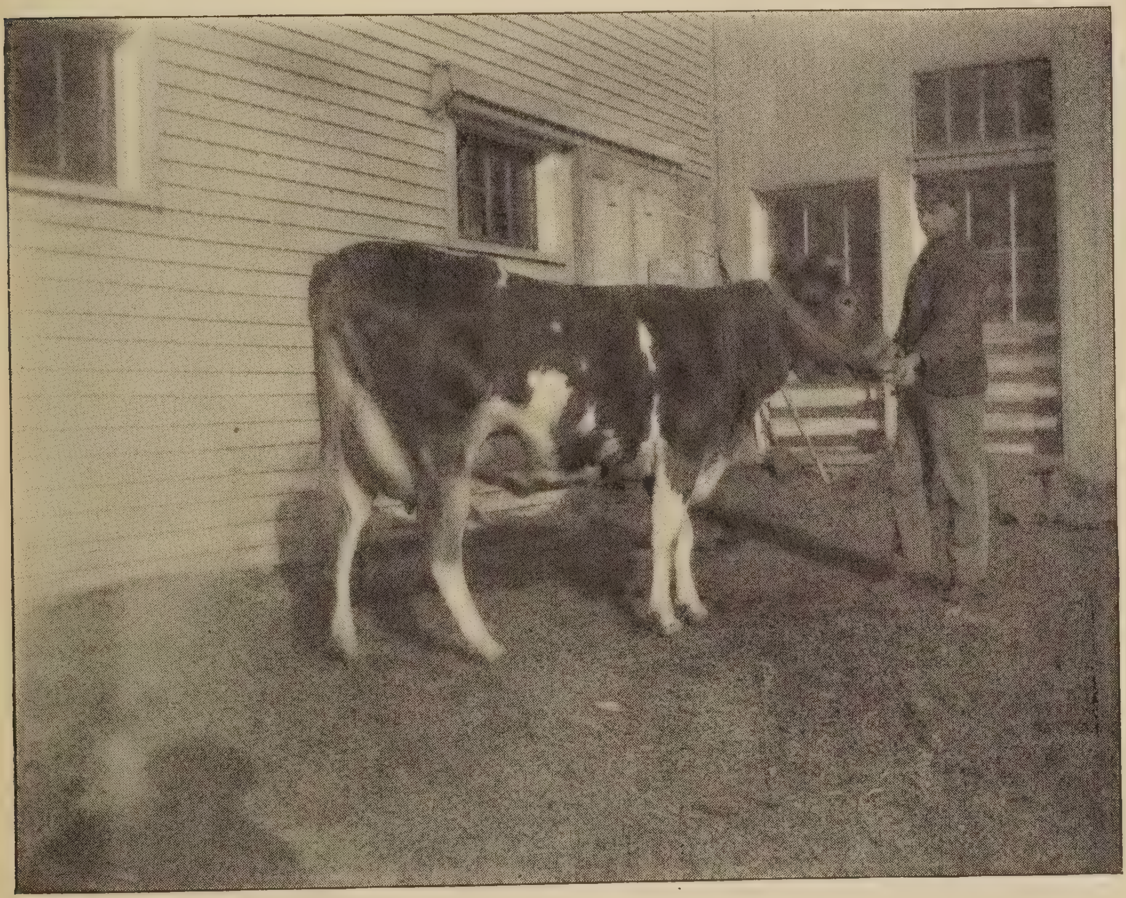


Fig. 21. Lilly Eurotas, 2nd.

The record shows that Lilly Eurotas, 2nd, gave in one year 6,294 pounds of milk containing 320 pounds of fat, equivalent to 373 pounds of butter. To be admitted to the Guernsey Advanced Registry, a heifer of this age (3 years and 193 days) must produce 306.3 pounds of fat. Lilly Eurotas, 2nd, exceeded the requirements by nearly 14 pounds.*

* The Guernsey Cattle Club do not permit a representative of an experiment station to supervise a test for the advanced registry when the cow is owned by the agricultural college, both institutions having the same Board of Control. Owing to this technical ruling the record will probably not be accepted by the Club. C. L. B.

TABLE 66.

Record of Lilly Eurotas, 2nd.

	Pounds Milk.	Babcock Test.	Pounds Butter Fat.
Aug. 20–31, 1903, - - - - -	282.1	4.55	12.83
September, - - - - - - -	619.2	4.40	27.24
October, - - - - - - -	631.4	4.9	30.94
November, - - - - - - -	581.0	4.9	28.47
December, - - - - - - -	568.5	5.	28.42
January, 1904, - - - - -	592.0	5.3	31.37
February, - - - - - - -	527.7	5.46	28.81
March, - - - - - - -	568.6	5.3	30.13
April, - - - - - - - -	497.0	5.	24.85
May, - - - - - - - -	509.8	5.	25.49
June, - - - - - - - -	459.0	5.6	25.53
July, - - - - - - - -	234.2	6.3	14.75
Aug. 1 to Aug. 19, 1904, - - -	223.6	5.0	11.18
	6294.1	5.08	320.01

OXYGEN IN MILK FEVER.

BY DR. E. H. LEHNERT.

Case at C. A. C., May 24, 1904. Physical condition excellent; in fact, the cow was so fat that Professor Beach anticipated milk fever. She calved on the morning of the 23d early, and was apparently in normal condition until the evening of the 24th. When seen at 10:15 P. M., she was just beginning to collapse, was lying down, and was made to rise with difficulty. She was unable to stand, staggered, and fell. From 10:15 till 10:40 she grew steadily worse, so that when the gas was administered she was unconscious and lying with head on side (typical position).

At 10:40 oxygen was injected into udder, after milking out and carefully disinfecting teats. The gas was allowed to flow gently into udder until it was tense and full, then ends of teats were compressed, and vigorous massage applied. At 11 P. M. the cow was lying in natural position with head held up, and was quite bright and perfectly conscious.

At 12:15 she was still brighter, and was eating hay, although still recumbent. At 1:30 A. M., same condition. At 3 A. M., very comfortable. Got up and ate hay, in all respects seemed quite normal, except a little weak. At 5 A. M. standing, chewing cud. From this time nothing abnormal was noticed, except perhaps that she was inclined to lie down more than usual, and the flow of milk was small for a few days. No trouble with udder or digestion at any time.

On June 9th, sixteen days after coming down with the disease, the cow gave thirty-four pounds of milk, and was being forced for a record which would make her eligible to the advanced registry.

She is now in the advanced registry.

SKIM MILK FOR MILCH COWS.

REPORTED BY C. L. BEACH AND A. B. CLARK.

Availability of nutrients of skim milk.—The constituents of skim milk may be regarded as wholly digestible, except when fed as an exclusive diet, in which case a small part may escape digestion. The value of skim milk in a ration, however, is greater than the digestible composition would indicate. For example, Professor Henry of the Wisconsin Experiment Station has shown, as the average of nineteen trials, that 475 pounds of skim milk, when fed to pigs, is equal to 100 pounds of corn meal. The digestible nutrients in these amounts is shown in the table below.

TABLE 67.

	Protein.	Carbo-Hydrates.	Fat.	Total Digestible Nutrients.
100 Corn meal, - - - -	7.9	66.7	4.3	78.9
475 Separator skim milk, -	13.775	24.7	1.425	39.9

The above indicates that one pound of digestible nutrients in skim milk for pig feeding is equal to two pounds of digestible nutrients in corn meal. The superior value of the digestible nutrients of skim milk over those in corn meal may be explained in part on the supposition that less energy is required to make the nutrients available to the animal in the former food than in the latter.

Skim milk for milch cows.—The feeding value of skim milk in a ration for dairy cows has been reported in but few trials, and the practice of feeding skim milk to milch cows is not at all common. Our experience lends little encouragement to the practice of utilizing the by-products of the dairy as a food for the cow, as few can be induced to drink it. Twenty-four cows in the herd were offered sweet separator milk, and only four of

this number would drink it. Grain was placed on the milk, and water was withheld forty-eight hours, but all the expedients used to induce the remaining twenty cows to drink the milk resulted in failure. The four cows, however, consumed the milk greedily and with apparent relish. One of the cows aborted during the trial, and her record is not reported. The records of the three cows receiving the skim milk and of nine cows receiving the ordinary ration are reported below. Skim milk was substituted for one-half the grain ration at the rate of eight pounds of skim milk to one of grain. In this proportion it was assumed that the total nutrients in the skim milk replaced the digestible nutrients in the grain, pound for pound. The grain ration consisted of a mixture of four parts of bran and one part of cotton seed meal. During Period I. the three cows received skimmed milk in place of one-half the concentrates, during Period II. grain only, and in Period III. the same as in Period I. The roughage, consisting of hay and silage, was uniform during the three periods. The ration of the nine cows used as a check was uniform for the three periods.

TABLE 68.

Skim Milk vs. Grain.

	Three Cows.				Nine Cows on Uniform Ration.
	Hay and Silage	Ration.		Product.	
		Concent's. Pounds.	Skim Milk Pounds.	Milk Flow. Pounds.	Milk Flow Pounds.
Period I., - -	Uniform amount fed during three periods.	252	2016	1335	2688
Period II., - -		504	none	1284	2678
Period III., -		252	2016	1383	2672

Average increase, Periods I. and III., 75 pounds.

For Periods I. and III., the average milk flow for the cows receiving skim milk was 1,359 pounds, or 75 pounds more than in Period II. The money value of this increased milk flow, at three cents per quart, is $1.05. The 252 pounds of grain saved, at $22 per ton, is worth $2.77. The 2,016 pounds of skim milk resulted in a saving in this trial, therefore, of $3.82, which is equivalent to nineteen cents per cwt.

THE EFFECT OF SILAGE ON THE ACIDITY OF MILK.

REPORTED BY B. B. TURNER AND C. L. BEACH.

The milk of two cows, "Naomi's Beauty" and "Ethel's Fancy," was titrated with a standard soda solution, using phenol phthalein as indicator. All results are calculated as per cent. of lactic acid. Preliminary experiments showed that the almost total absence of lactic acid bacteria in the college barn made special precautions against souring almost unnecessary. The milk showed no increase of acidity after standing in the laboratory at ordinary temperature for one or two days. A slight decrease in acidity in the first few hours was noticed. However, the samples were taken direct into clean bottles, and were kept in cold storage until titrated, usually the same day. The milk of both cows was treated exactly alike, and was titrated simultaneously. The test covered three periods. During Period I. both cows were fed a ration containing about forty pounds of silage per day, which they had been receiving for five months or more. In period II. Naomi's Beauty was fed on the silage ration, while Ethel's Fancy received a ration without silage. During Period III. the ration was changed for both, Ethel's Fancy going back to the silage, while Naomi's Beauty received none. The results are given below.

TABLE 69.

Result of Acidity Test.

PERIOD.	Length of feeding period.	No. of samples.	NAOMI'S BEAUTY.		ETHEL'S FANCY.	
			Silage.	No silage.	Silage.	No silage.
I. - -	Up to May 13th,	3	0.11%	—	0.16%	—
II. - -	May 13th to 20th,	4	0.11%	—	—	0.19%
III. -	May 20th to 27th,	9	—	0.13%	0.19%	—

As may be seen from these figures, there was apparently a slight increase in acidity when the cows were "taken off" a silage ration, but the difference is so small that it may probably be attributed to chance variations. There is a much more noticeable difference between individual cows, as is shown by the following analyses, all on silage rations: "Brownie," average of six analyses, 0.19 per cent.; "Molly 2d," average of six analyses, 0.185 per cent.; "Naomi's Beauty," average of seven analyses, 0.11 per cent., and "Ethel's Fancy," average of twelve analyses, 0.175 per cent. The mixed milk of the herd of 25 cows on grass (May 25th to 27th) showed as an average of six analyses 0.175 per cent. of acidity.

DISCUSSION OF THE AMOUNT OF PROTEIN REQUIRED IN THE RATION FOR DAIRY COWS.

BY C. L. BEACH.

During the winter of 1892–3 a representative of the Experiment Station visited sixteen dairy farms and made systematic observation of the cows, their feeding, care, milk and butter fat production, and kindred subjects.

Weights of milk flow for five days.—"The milk of each cow at each milking was weighed as soon as milked to the nearest tenth of a pound by the Station representative." *

Percentages and amounts of butter fat in the milk.—"A sample of the milk of each cow, at each milking, was taken for the determination of the quantity of butter fat. The Babcock method of fat determination was employed. From the percentages of butter fat in the milk and the total weights of milk, the daily yield of butter fat was obtained."

Kinds and weights of foods used.—"The feeder was requested to use the same kinds and amounts of feeding stuffs during the test period as he had previously used. The quantity for each animal was weighed by the Station representative just before feeding. Any portions of the food left uneaten by the cows was carefully weighed, and due allowance was made for these uneaten residues in estimating the amounts eaten daily. During the test, usually on the third day, samples of each food used were carefully taken and at once sent to the laboratory for analysis. From the results of the analyses and the weights for feed, the total nutrients (protein, fats, nitrogen free extract, and fiber) fed each day were calculated. By the use of digestion co-efficients, more or less accurate estimates were made of the weights of digestible nutrients in each day's ration."

The herds under observation were numbered from 1 to 16 inclusive.

* Report Storrs Expt. Station, 1893.

"In the second winter's work, 1893-4, six different herds were visited, and in four cases the time of study of the management and products of each herd was extended to twelve days. The analyses of the feeding stuffs were made at once, and the weights of nutrients were calculated." The herds observed during this winter's work were numbered as follows: 18, 19, 20, 21, 22, 24, and 26.

"During the third winter, 1894-5, four herds were visited, each herd being under observation for twelve days." Numbers 27, 28, 31, and 32.

"During the winter of 1895-6, two herds were studied in a similar manner." Numbers 35 and 36.

The work of the fifth winter, 1896-7, included studies of four herds. Numbers 39, 40, 43, and 44.

In the winter of 1899-1900 tests were made with four herds. Numbers 51, 52, 55, and 56. "The herds were fed according to the usual practice of the dairyman, and the amounts and composition of the feeds used and of the milk production were determined. It was found that generally a uniform grain ration was fed to all the cows of the herd, although in some cases it was varied in amount somewhat according to the yields of milk."

"In the winter of 1900-01 four herds were included in the studies, and observations made in the usual manner. Numbers 59, 60, 63, and 65."

In this discussion, the rations fed the herds before mentioned are designated as 'original rations.' At periods varying from two to four weeks after the original observations were made, twenty of the herds were fed a ration recommended by the Station. The rations fed during the second test of the herds will be designated as 'recommended rations,' and will be referred to later on in this discussion. The forty 'original rations' were those found in use by Connecticut dairymen during the period mentioned. For convenience of study they are grouped into two divisions, according to the amounts of digestible protein in the ration. Those containing less than 2.01 pounds of digestible protein per day are placed in Table 71, and those containing more than 2.01 pounds of digestible protein per day in Table 72.

In Tables 71, 72, 73, 75, 76, 77 and 78,

Column 1 gives the number of the test.

Column 2 gives the number of cows in the herd.

Column 3 gives the pounds of digestible protein in the ration.

Column 4 gives the calories in the ration.

Column 5 gives the pounds of grain in the ration.

Column 6 gives the pounds of dry roughage in the ration.

Column 7 gives the pounds of silage in the ration.

Column 8 gives the average milk yield in pounds.

Column 9 gives the average butter yield in pounds.

Column 10 gives the average cost of the ration.

Column 11 gives the estimated manurial value of the ration.

Prices of feed, *Table 70*.—The prices assumed in estimating the cost of the ration are uniform for the entire period, and are such as prevailed in the markets of Connecticut for the winter of 1903-04. The Connecticut State Station, in its inspection work of feeding stuffs,* obtained the retail price per ton for various feeds. Prices were obtained from forty-eight towns and villages, and so far as applicable they have been used in this calculation. The cost of cotton seed meal is the average of prices from twenty-five dealers, bran of sixteen dealers, hominy meal of twenty-four dealers, etc.

Bog hay and black grass were valued at $8 per ton; poor or medium hay, Hungarian hay, oat and pea hay at $12 per ton; clover and rowen at $14, and mixed hay at $16 per ton. All hay was assumed to be "mixed" unless otherwise designated.

Column 3 of Table 70 shows an estimated manurial value in one ton of the feeding stuffs. In this calculation nitrogen was rated at 15 cents per pound, phosphoric acid at 5 cents, and potash at 4½ cents,† and it is assumed that one-half of the fertilizing elements in the food will be obtained in the manure.‡

* Bulletin No. 145.

† The values of the several ingredients vary from year to year with the cost of fertilizers. The ratings for phosphoric acid and potash are full high for present market prices of commercial fertilizers.

‡ It is a common custom to assume that two-thirds of the fertilizing ingredients of the feed will appear and be available in the manure. It is questionable, however, as manure is handled on the average farm, if two-thirds or even one-half of the fertilizing ingredients are ordinarily saved.

TABLE 70.

Valuation of Feeding Stuffs as Used in Rations.

NAME OF FEED.	Number of dealers.	Average retail price per ton.	Estimated net value obtainable from one ton of feeding stuffs.
Gluten feed,	14	$26 00	$5 10
Wheat middlings,	17	25 50	4 70
Wheat bran,	16	22 50	6 18
Cotton seed meal,*	25	29 04	12 00
Cream gluten,*	3	32 00	8 00
Malt sprouts,	3	19 00	6 72
O. P. Linseed,	9	30 77	9 50
Hominy meal,	24	24 28	3 15
Rye meal,	9	25 00	3 30
Wheat feed,	18	23 50	5 90
Provender,*	3	27 00	3 30
H. O. dairy feed,	2	29 50	5 30
Chicago gluten meal,*	—	28 00	8 00
Corn and cob meal,	—	15 00	2 60
Corn meal,	—	20 33	3 25
Oat feed,	—	20 00	2 15
Ground oats,	—	30 00	3 85
Mixed hay,	—	16 00	3 00
Clover hay, Rowen hay,	—	14 00	4 00
Medium quality mixed hay, Hungarian hay, Oat and pea hay,	—	12 00	3 00
Bog hay, Black grass, Oat straw,	—	8 00	2 00
Corn fodder,	—	10 00	3 30
Corn stover,	—	6 00	2 30
Silage,	—	3 00	65
Potatoes,	—	4 00	75

* It is well understood that prices of feed do not correspond with their feeding value. For example, cotton seed meal contains five times as much protein and practically the same amount of total nutrients as provender, and yet there is only two dollars difference in the selling price per ton. Based on composition, cream gluten should not be more valuable than Chicago gluten meal.

The cows in the two groups averaged 811 and 813 pounds of live weight, and the average period of lactation was 5.3 months in each group.

For convenience of comparison the averages of the food consumed and production of the two groups are placed in Table 73.

It may be assumed, perhaps, that the large number of cows included in these groups have, by counterbalance, eliminated differences in individuality. There are, however, four other variable factors in the comparison:

1. The rations B (Table 73) contain 0.71 pound more protein than do those designated A.

2. The rations B contain 2,888 more calories than do those designated A.

3. The rations B contain 1.5 pounds more grain than do those designated A.

4. The herds are not the same.

TABLE 71.

ORIGINAL RATIONS CONTAINING 2.01 POUNDS OF PROTEIN OR LESS.

Average Pounds of Grain and Roughage Fed per Cow per Day, with Protein Content and Fuel Value, also Average Daily Milk Flow and Yield of Butter.

No. of Test.	No. of Cows.	Lbs. Protein.	Calories.	Lbs. Grain.	Lbs. of Dry Roughage	Lbs. Silage and Roots.	Lbs. Milk.	Lbs. Butter.	Cost of Food Cents.	Val. Obt'n'ble Manure. Cts.
6, - - -	10	1.78	30,200	6.6	23.3	—	14.7	.77	22.35	—
7, - - -	17	2.01	35,150	11.6	20.1	—	20.4	1.08	30.10	—
9, - - -	12	1.89	26,200	5.7	19.5	—	15.0	.83	20.13	—
10, - - -	18	1.97	27,250	7.0	19.0	—	20.7	1.12	19.54	—
13, - - -	19	1.76	23,000	9.0	6.0	24.6	12.7	.69	14.46	—
15, - - -	19	1.15	26,300	7.6	17.5	—	13.6	.78	17.14	—
16, - - -	20	1.30	26,650	6.2	19.6	—	16.1	.87	20.28	—
20, - - -	15	1.49	25,800	9.1	18.4	—	18.1	.86	17.26	—
22, - - -	12	1.38	21,150	7.3	11.9	—	15.1	.70	13.58	—
26, - - -	15	2.00	22,900	8.5	11.4	—	13.2	.77	20.28	—
27, - - -	12	1.29	21,800	9.2	12.7	—	14.0	.76	14.29	—
28, - - -	14	1.63	30,650	10.9	15.2	—	17.9	.98	20.91	—
31, - - -	10	1.32	25,450	6.7	9.3	34.9	17.8	.97	15.20	—
35, - - -	11	1.42	26,600	7.3	17.7	—	16.7	.84	15.82	—
39, - - -	13	1.81	30,450	7.3	9.7	36.7	17.1	.86	20.98	—
40, - - -	9	1.76	30,900	6.5	10.9	29.4	16.9	1.02	17.45	—
55, - - -	18	1.49	27,270	6.2	8.5	27.5	15.9	.84	18.75	—
56, - - -	9	1.45	27,290	4.8	22.6	—	13.5	.78	19.76	—
59, - - -	13	1.75	27,960	8.6	17.8	—	14.1	.88	19.01	—
60, - - -	13	1.77	29,480	8.0	18.5	—	17.4	.98	19.41	—
Avg. of 20 herds,	279	1.62	27,122	7.7	15.5	7.6	16.0	.870	19.03	4.2

Group B yielded daily 2.6 pounds more milk and 0.16 pound more butter than did group A. Group B received daily 0.71 pound more protein than group A received, but it also received 1.5 pounds more grain, with the roughage about the same in both groups. The larger amounts of grain fed group B might

be expected to yield larger amounts of net available energy, and might, therefore, be expected to yield larger amounts of milk and butter fat.

The larger number of calories in the rations fed to group B may have caused the larger milk flow, but this may be doubted, as the number of calories in the rations fed to group A were sufficient for cows yielding 16.0 pounds of milk.

TABLE 72.

ORIGINAL RATIONS CONTAINING MORE THAN 2.01 POUNDS PROTEIN.

Average Pounds of Grain and Roughage Fed per Cow per Day, with Protein Content and Fuel Value, also Average Daily Milk Flow and Yield of Butter.

No. of Test.	No. of Cows.	Lbs. Protein.	Calories.	Lbs. Grain.	Lbs. of Dry Roughage	Lbs. Silage and Roots.	Lbs. Milk.	Lbs. Butter.	Cost of Food. Cents.	Val. Obt'n'ble Manure. Cts.
1, - - -	13	2.26	30,150	7.5	14.7	24.6	16.8	1.02	24.11	—
2, - - -	18	2.44	32,350	10.0	8.2	48.4	20.2	1.16	26.29	—
3, - - -	13	2.41	30,350	8.6	16.2	6.1	18.3	1.08	21.90	—
4, - - -	19	2.10	31,800	8.5	24.4	—	14.9	.92	24.21	—
5, - - -	15	2.53	31,500	6.6	10.6	26.4	19.4	.90	21.58	—
8, - - -	12	2.37	31,000	9.2	21.5	—	17.6	.96	25.46	—
11, - - -	18	2.34	29,250	8.5	19.2	—	15.6	.90	23.10	—
12, - - -	20	2.61	26,850	11.4	6.5	36.0	21.5	1.09	23.16	—
14, - - -	10	2.33	29,500	8.1	19.6	—	18.5	1.04	24.12	—
18, - - -	15	2.15	32,750	10.1	16.6	10.0	18.8	1.10	26.07	—
19, - - -	15	2.23	27,550	8.8	15.6	—	17.3	1.03	17.56	—
24, - - -	14	2.70	29,100	10.6	15.7	—	17.9	1.03	20.97	—
32, - - -	14	2.14	26,700	8.1	14.2	—	17.7	.95	18.78	—
36, - - -	14	2.34	28,850	9.4	17.1	2.0	17.0	1.02	20.99	—
43, - - -	9	2.11	25,400	11.4	10.2	4.2	22.1	1.29	17.98	—
44, - - -	8	2.12	30,150	11.8	15.0	—	22.8	1.26	21.72	—
51, - - -	13	2.71	31,990	11.7	7.7	29.9	16.6	1.00	25.44	—
52, - - -	8	2.23	28,800	3.8	23.5	—	13.9	.88	19.86	—
63, - - -	17	2.19	35,140	11.8	21.4	—	19.4	1.04	22.64	—
64, - - -	30	2.40	30,990	8.2	11.3	22.5	19.6	1.03	23.13	—
Avg. of 20 herds,	295	2.33	30,010	9.2	15.46	10.5	18.6	1.03	22.45	5.0

The food cost of rations B was 3.42 cents more than A and the estimated value of the obtainable manure was 0.8 cent more.

On the basis of 2.15 pounds to the quart, the food cost of a quart of milk and a pound of butter from rations A and B are as shown in Table 74.

TABLE 73.

COMPARISON OF AVERAGE OF 20 RATIONS HIGH AND LOW IN PROTEIN.

Average Pounds of Grain and Roughage Fed per Cow per Day, with Protein Content and Fuel Value, also Average Daily Milk Flow and Yield of Butter.

No. of Test.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Val. Obtainable Manure. Cts.
20 A, - -	279	1.62	27,122	7.7	15.5	7.6	16.0	.87	19.03	4.2
20 B, - -	295	2.33	30,010	9.2	15.46	10.5	18.6	1.03	22.45	5.0
Difference, -		+.71	+2,888	+1.5	−.04	+2.9	+2.6	+.16	+3.42	+.8

The average group B cow made more milk and butter than did the average group A cow, but at an extra cost. These practically offset each other, so that the food cost and net cost of a quart of milk from cows in group B were slightly higher than from cows in group A, while the food cost and net cost of a pound of butter were slightly lower. The differences in the cost of a unit of product are too small to constitute a formidable argument in favor of either ration.

TABLE 74.

Cost of One Quart of Milk and One Pound of Butter with Rations Low and High in Protein.

	Lbs. of Protein Eaten.	Food Cost 1 qt. of Milk.	Net Cost 1 qt. of Milk.	Food Cost 1 lb. of Butter.	Net Cost* of lb. of Butter.
Group A, - - - - -	1.62	2.557c	1.993c	21.87c	17.05c
Group B, - - - - -	2.33	2.595c	2.020c	21.79c	16.94c
Difference, - - - -		+.038c	+.027c	−.08c	−.11c

* The term net cost as here used is the difference between the food cost of the ration and its manurial value.

On the other hand, it is to be noted that the increased production of group B, while secured at practically the same food cost per unit of product, really represents a lower final cost per unit of product when the items of labor, stabling, interest, etc.,

are taken into account. But this increase of production may be attributed either to the additional protein in the rations, or to the additional grain, or to both.

"*Recommended Rations.*"—"In the winter's work of 1893–4, three herds which had been observed for a period of twelve days were fed on a ration suggested by the Station as being better than the ones which had been used. The owners gradually changed the food to the ration thus proposed, and after an interval of four weeks from the close of the first test another twelve days' test was made of the same herd. A comparison was thus made of the yields of milk and butter fat with the two different rations."

"During the winter of 1894–5, four herds were fed a 'recommended' ration after the observation test, in the same manner as the three other herds studied the previous year, except that there was only a two weeks' interval between the two tests of the same herd."

"During the fourth winter, 1895–6, two herds were studied in a similar way, except that in one case a ration with a much larger quantity of protein was used. Nine days elapsed between the two tests, and the change from one ration to the other was made under the supervision of the person in charge of that experiment. In one case, the first ration had a much larger amount of protein than we have commonly found on dairy farms in this State. In both cases the amount of protein increased in the second ration."

"In the work of the fifth winter, 1896–7, studies of four herds were made according to the methods of the two previous years. Two weeks were allowed for changing the feeds between the tests of the same herd. In the rations fed to one of the herds, the nutritive ration in the first test was as narrow as in the standard tentatively suggested by the Station, but in this case as in the others the second ration was made still narrower."

The tests for 1897–8 have not been published.

"In 1899–1900 four herds were studied. In the second test the ration was proposed by the Station, and was determined for each herd by the production of butter fat by the cows in the herd. The cows were arranged in groups according to the average daily amount of butter fat produced by each cow during the first test, and all the cows in a group were fed uniformly.

The ration consisted of two parts, a basal ration and an additional grain ration. The basal ration was made up of coarse fodders and grain feeds in various proportions, the whole intended to furnish two pounds of digestible protein. The additional grain feed was made up of different concentrated feeding stuffs mixed together in various proportions depending upon composition. This for convenience is called a 'protein mixture,' and was planned to furnish three-tenths of a pound of digestible protein for each pound of mixture. All the cows in the test were given the same basal ration, but the amount of protein mixture added to it depended upon the amount of butter fat the cows had produced."

"In the winter of 1900–01 four herds were studied a second time, after an interval of four weeks from the close of the preceding test. In the second test the ration was proposed by the Station, and was based upon the yields of butter fat. In the preliminary tests, designated as 'original rations,' as a common thing each farmer fed all the cows a uniform ration, although in some cases the amount of grain feeds was varied slightly for the different cows according to whether they were fresh or well advanced in lactation."

In all, twenty-one herds containing 277 cows were fed a narrow ration in comparison with a wider ration fed from two to four weeks previously.

For the sake of comparison the twenty-one original rations are grouped in Table 75, and the "recommended rations" fed the same herds are grouped in Table 76.

The average estimated live weight of the cows in the twenty-one herds in the original tests was 760 pounds. The second test, on the recommended rations, began on the average four weeks after the beginning of the first test, and the cows were, therefore, four weeks farther advanced in lactation. The herds averaged about five months in lactation at the beginning of the first test. "The normal rate of shrinkage in milk flow that would usually occur under an efficient average unchanged ration is 2½ per cent. for every one-half month during the fourth and fifth month" (Geneva Station Bul. 210). For four weeks (1 month) this shrinkage for cows giving 17.25 pounds of milk per day would amount to .85 pound. Whether or not this calculated shrinkage is applicable to the herds fed the recommended ration and under *changed conditions* will be discussed later.

TABLE 75.

ORIGINAL RATIONS.

Average Pounds of Grain and Roughage Fed per Cow per Day, with Protein Content and Fuel Value, also Average Daily Milk Flow and Yield of Butter.

No. of Test.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Est. Val. Obtainable Man're. Cts.	Net Cost of Ration. Cents.
27, - -	12	1.29	21,800	9.2	12.7	—	14.0	.76	14.29	3.1	—
31, - -	10	1.32	25,450	6.7	9.3	34.9	17.8	.97	15.20	3.5	—
55, - -	18	1.49	27,270	6.2	8.5	27.5	15.9	.84	18.75	3.6	—
60, - -	13	1.77	29,480	8.0	18.5	—	17.4	.98	19.41	4.6	—
22, - -	12	1.38	21,150	7.3	11.9	—	15.1	.70	13.47	3.2	—
39, - -	13	1.81	27,950	7.3	9.7	36.7	17.1	.86	20.98	4.5	—
43, - -	9	2.11	25,400	11.4	10.2	4.2	22.1	1.29	17.98	4.3	—
32, - -	14	2.14	26,700	8.1	14.2	—	17.7	.95	18.78	4.0	—
20, - -	15	1.49	25,800	9.1	18.4	—	18.1	.86	17.26	4.1	—
35, - -	11	1.42	26,600	7.3	17.7	—	16.7	.84	15.82	4.0	—
44, - -	8	2.12	30,150	11.8	15.0	—	22.8	1.26	21.72	4.2	—
40, - -	9	1.76	30,900	6.5	10.9	29.4	16.9	1.02	17.45	4.4	—
56, - -	9	1.45	27,290	4.8	22.6	—	13.5	.78	19.80	4.3	—
28, - -	14	1.63	30,650	10.9	15.2	—	17.9	.98	19.94	4.1	—
59, - -	13	1.75	27,960	8.6	17.8	—	14.1	.88	19.00	4.4	—
18, - -	15	2.15	32,750	10.1	16.6	10.0	18.8	1.10	26.07	5.7	—
36, - -	14	2.34	28,850	9.4	17.1	2.0	17.0	1.02	20.99	4.5	—
51, - -	13	2.71	31,990	11.7	7.7	29.9	16.6	1.00	25.44	5.5	—
52, - -	8	2.23	28,800	3.8	23.5	—	13.9	.88	19.86	4.9	—
63, - -	17	2.19	35,140	11.8	21.4	—	19.4	1.04	22.64	5.7	—
64, - -	30	2.40	30,990	8.2	11.3	22.5	19.6	1.03	23.13	5.0	—
Av. of 21 herds, 277 cows, - - -		1.85	28,240	8.49	14.77	9.4	17.25	.954	19.43	4.4	15.03

The twenty-one herds, containing 277 cows, four weeks later in lactation, gave daily, per cow, 0.25 pound more milk and .056 pound more butter with the recommended ration than with the original. The food cost of the recommended ration was 0.23 cent less, and the net cost was 0.73 cent less per cow per day. The recommended ration contained 0.51 pound more protein, 1,070 less calories, 0.66 pound more grain and less roughage than the original.

In comparing the original with the recommended ration it should be noticed that there are five variable factors:

1. The calories are less in the recommended than in the original ration.

Table 76.

RECOMMENDED RATIONS.

Average Pounds of Grain and Roughage Fed per Cow per Day, with Protein Content and Fuel Value, also Average Daily Milk Flow and Yield of Butter.

No. of Test.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Est. Val. Obtainable Man're. Cts.	Net Cost of Rations. Cents.
29, - - -	12	2.09	25,350	12.4	9.7	—	13.7	.89	16.75	4.1	—
33, - - -	10	2.23	26,850	8.8	15.7	—	18.5	1.01	19.44	5.1	—
57, - - -	18	2.36	27,400	8.2	12.0	6.4	16.8	.96	20.26	4.4	—
62, - - -	13	2.43	29,610	10.5	16.0	—	18.0	1.10	21.86	5.7	—
25, - - -	12	1.80	22,400	7.8	12.2	—	15.9	.79	16.16	3.7	—
42, - - -	9	2.31	28,000	8.3	8.8	28.9	17.0	1.10	18.76	5.2	—
45, - - -	9	3.26	26,050	11.4	11.6	—	23.4	1.33	19.18	5.2	—
34, - - -	14	2.16	26,200	7.9	14.0	—	15.4	.87	16.78	4.9	—
23, - - -	15	2.00	24,700	8.8	17.2	—	17.9	.89	17.10	4.6	—
37, - - -	11	2.27	25,050	6.8	15.6	—	17.4	.90	15.72	4.0	—
46, - - -	8	3.12	29,500	11.4	13.3	—	21.4	1.27	21.50	5.0	—
41, - - -	13	2.44	27,600	8.2	6.9	28.4	16.6	.91	19.42	4.8	—
58, - - -	9	1.87	26,460	7.3	16.7	—	16.7	1.03	17.98	4.3	—
30, - - -	14	1.81	24,950	8.9	13.3	—	18.3	1.03	17.48	4.5	—
61, - - -	13	1.90	24,860	9.0	16.0	—	14.7	.95	18.02	4.7	—
21, - - -	15	2.39	29,400	10.3	11.0	12.6	18.9	1.08	22.05	5.5	—
38, - - -	14	2.74	27,950	10.2	14.7	2.0	17.4	1.10	20.79	5.7	—
53, - - -	13	2.92	30,950	10.5	8.3	31.3	16.2	1.02	22.74	5.9	—
54, - - -	8	2.37	27,250	6.2	19.2	—	16.3	.98	20.20	5.0	—
65, - - -	17	2.34	30,320	10.5	17.0	—	19.1	1.06	18.88	4.90	—
66, - - -	30	2.74	29,710	8.7	10.0	22.5	18.1	1.00	22.25	5.5	—
Ave'ge of 21 herds, 277 cows, - - -		2.36	27,170	9.15	13.3	6.3	17.5	1.01	19.20	4.90	14.30

2. The grain is more in the recommended than in the original ration.

3. The protein is more in the recommended than in the original ration.

4. The recommended rations were fed later in the period of lactation than were the original rations.

5. Grain was apportioned to the cows in the recommended rations according to the milk flow or butter fat production.

The effect on the milk flow of these factors will be discussed in the above order.

TABLE 77.

COMPARISON OF AVERAGES OF 21 ORIGINAL AND 21 RECOMMENDED RATIONS.

Average Pounds of Grain and Roughage Fed per Cow per Day, with Protein Content and Fuel Value, also Average Daily Milk Flow and Yield of Butter.

No. of Herds.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Est. Val. Obtainable Man're. Cts.	Net Cost. Cents.
D. 21, -	277	1.85	28,240	8.49	14.77	9.4	17.25	.954	19.43	4.4	15.03
R. 21, -	277	2.36	27,170	9.15	13.30	6.3	17.50	1.010	19.20	4.9	14.30
Difference,		+.51	−1,070	+.66	−1.47	−3.1	+.25	+.056	−.23	+.5	−.73

1. The Wolff standard for a 1,000-pound dairy cow giving an average quantity of milk called for 15.4 pounds of total nutrients, of which 2.5 pounds should be protein, 12.5 pounds carbohydrates, and 0.4 pound fat. This amount of total nutrients is equivalent to 29,588 calories. Kuhn gives the requirements for maintenance for a cow weighing 1,000 pounds as 0.7 pound of protein and 6.6 pounds of nitrogen free extract, which is equivalent to 13,578 calories.

The cows in these tests weighed 760 pounds, and there would be required for maintenance 5.55 pounds of nutrients, equivalent to 10,320 calories. The amount of total nutrients required, therefore, for a cow weighing 760 pounds and giving an average quantity of milk may be assumed to be (15.4—1.75) 13.65 pounds, equivalent to 26,330 calories.

The calories in the original ration averaged 28,240 against 27,170 in the recommended one. The latter amount is still above the theoretical needs of the cow. The depression of the recommended rations as compared with the original rations to the extent of 1,070 calories, and this in the form of roughage, may have been an advantage to the cows consuming them, rather than a disadvantage.

This point is borne out by a comparison of the original and recommended rations in this particular. In Table 78 the original and recommended rations are grouped as follows: In the upper

division are those in which the calories were increased in the recommended rations, in the middle division are those in which the calories were below 27,000 and were decreased in the recommended rations, and in the third division are those in which the calories were above 27,000 in the original rations, and were decreased in the recommended.

TABLE 78.

Comparison of Original and Recommended Rations.

A. Calories increased.
B. Calories decreased when below 27,000.
C. Calories decreased when above 27,000.

No. of Tests.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Est. Val. Obtainable Man're. Cts.
A.										
O. 7, - -	87	1.59	25,500	8.0	11.5	14.8	17.05	.91	17.15	3.8
R. 7, - -	87	2.35	26,520	9.6	12.3	5.0	17.61	1.02	18.91	4.8
Difference,		+.76	+1,020	+1.6	+.8	—9.8	+.55	+.11	+1.76	+1.0
B.										
O. 3, - -	40	1.68	26,360	8.2	16.7	—	17.5	.88	17.28	4.0
R. 3, - -	40	2.14	25,320	7.8	15.6	—	16.9	.88	16.53	4.5
Difference,		+.46	—1,040	—.4	—1.1	—	—.6	0	—.75	+.5
C.										
O. 11, -	150	2.07	30,500	8.9	16.3	8.5	17.32	.999	21.46	4.8
R. 11, -	150	2.42	28,090	9.2	13.3	8.8	17.61	1.04	20.12	5.1
Difference,		+.35	—2,410	+.3	—3.0	+.3	+.29	+.041	—1.34	+.3

(A) Table 78, upper division.—With seven herds of eighty-seven cows the recommended ration contained more protein, more calories, 1.6 pounds more grain, and less roughage than the original rations. The gain in milk is 0.55 pound.

(B) Middle division.—With three herds of forty cows, the recommended ration contained more protein, less calories (calories decreased when below 27,000), less grain, and less roughage. The average shrinkage in milk is 0.6 pound.

(C) Lower division.—With eleven herds of one hundred and fifty cows, the recommended ration contains 2,410 less calories (calories decreased when above 27,000), 0.3 pound more grain, and less roughage. The gain in milk is 0.29 pound.

The gain in (C) of 0.29 pound of milk is a little larger than the average gain of all the herds, although the calories are decreased twice as much as the average of all.

The conclusion seems to be warranted, therefore, that the lowering of the recommended rations to the extent of 1,070 calories did not depress the milk flow (Table 77). Or, to put it another way, the milk flow from the recommended rations would not have been larger if the former supply of calories had been maintained.

2. *The effect of increase of grain on milk flow.*—Zuntz and Lehman report that the work of chewing the food and digesting it, in the case of the horse, may represent a considerable portion of the nutrition of the food. The effort of chewing hay represents 11.2 per cent. and in the case of oats 2.8 per cent. of the total energy yielded by the food (Henry's Feeds and Feeding, page 29).

"According to Wolff's experiments, 2.5 pounds of good meadow hay have an equal nutritive value to 1.5 pounds of oats, if the digestible crude fiber be included in both cases."* There are 1.19 pounds of digestible nutrients in 2.5 pounds of hay, and 0.91 pound of digestible nutrients in 1.5 pounds of oats.

Henry has shown that 475 pounds of skim milk are equivalent to 100 pounds of corn meal for pig feeding (Henry's Feeds and Feeding, page 572).

There are 78.9 pounds of digestible nutrients in 100 pounds of corn meal, and 37.9 pounds of digestible nutrients in 475 pounds of skim milk. One pound of nutrients in skim milk is worth twice as much, therefore, as one pound in corn meal.

The same principle is illustrated in horse feeding. When work is heavy, the proportion of grain to roughage is increased; and when labor is lessened, the roughage may be increased, and the grain decreased.

* Ldw. Jahrb., XXIV., p. 267.

There is, then, more net available energy in a pound of digestible nutrients in grain than in roughage. Of two rations otherwise equal, the one having the more grain should prove more effective.

TABLE 79.

Effect of Grain on Milk Flow.

A. Grain increased more than 1 pound and from below 8.
B. Remainder in which grain was increased.
C. Grain decreased.

No. of Test.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Est. Val. Obtainable Man're. Cts.
A.										
O. 7, - -	80	1.69	28,160	6.2	14.7	18.4	16.07	.904	18.78	4.2
R. 7, - -	80	2.29	27,595	8.2	13.6	9.1	17.13	1.01	19.70	4.9
Difference,		+.60	—565	+2.0	—1.1	—9.3	+1.06	+.106	+.92	+.7
B.										
O. 7, - -	105	1.92	26,985	9.1	13.9	5.5	17.24	.968	19.27	4.3
R. 7, - -	105	2.42	26,540	9.97	12.2	5.3	17.44	1.020	19.31	5.0
Difference,		+.50	—445	+.87	—1.7	—.2	+.20	+.052	+.04	+.7
C.										
O. 7, - -	92	1.95	29,575	10.1	15.7	4.3	18.45	.990	20.23	4.5
R. 7, - -	92	2.37	27,380	9.25	14.1	4.5	17.95	1.000	18.60	4.8
Difference,		+.42	—2,195	—.85	—1.6	+.2	—.50	+.010	—1.63	+.3

Table 79, upper division.—With seven herds of eighty cows, the grain in the recommended ration is increased 2 pounds, and the milk flow is larger by 1.06 pounds.

Middle division.—With seven herds of one hundred and five cows, the grain ration is increased by 0.87 pound, and the milk flow is 0.2 pound larger.

Lower division.—With seven herds of ninty-two cows, the grain ration is 0.85 pound less than in the original ration, and the milk flow is 0.5 pound smaller.

The amount of protein eaten is increased in all three cases.

TABLE 80.

Effect of Change in Protein.

A. Protein below 1.50 pounds in original ration and increased more than 0.4 pound; average increase, 0.69.

B. Protein above 1.50 pounds in original ration and increased more than 0.3 pound; average increase, 0.68.

C. Protein increased less than 0.24; average increase, 0.17.

No. of Test.	No. of Cows.	Lbs. of Protein.	Calories.	Lbs. of Grain.	Lbs. of Dry Roughage.	Lbs. of Silage and Roots.	Lbs. of Milk.	Lbs. of Butter.	Food Cost. Cents.	Est. Val. Obtainable Man're. Cts.
A.										
O. 7, - -	87	1.40	25,050	7.23	14.4	9.0	15.87	.821	16.37	3.9
R. 7, - -	87	2.09	25,460	8.60	14.1	.9	16.70	.924	17.63	4.3
Difference,		+.69	+410	+1.37	−.3	−8.1	+.83	+.103	+1.26	+.4
B.										
O. 7, - -	96	2.04	29,103	8.94	13.2	13.5	18.98	1.065	20.24	4.5
R. 7, - -	96	2.72	28,350	9.80	11.6	11.9	18.84	1.116	20.54	5.3
Difference,		+.68	−753	+.86	−1.6	−1.6	−.14	+.051	+.30	+.8
C.										
O. 7, - -	94	2.10	30,570	9.30	16.6	5.7	16.91	.975	21.67	4.9
R. 7, - -	94	2.27	27,700	9.04	14.1	6.3	16.98	.998	19.45	5.1
Difference,		+.17	−2,870	−.26	−2.5	+.6	+.07	+.023	−2.22	+.2

3. *Effect of protein on milk flow.*—An 800-pound cow needs for maintenance about 0.56 pound of protein per day, and when yielding 18 pounds of five per cent. milk, about 0.7 pound to replace the protein withdrawn in the form of casein and albumen. In addition, a certain amount of protein is consumed by the animal organism in the process of milk formation. An additional amount may be a stimulant to milk production. The amount of protein as well as other nutrients needed by the cow has been determined by experiments—with variable results—and expressed in feeding standards.

The Wolff standard allotted 2.5 pounds of protein to a cow weighing 1,000 pounds and giving an average quantity of milk, as did also the Atwater and Phelps proposed standard. The Wolff-Lehman standard, however, called for 2.5 pounds of

protein only when the cow was yielding 22 pounds of milk. The German standards have been generally accepted in this country since their introduction in 1874.

Some authorities have, however, advocated less amounts of protein, and some experiments would seem to show that the smaller amounts may sustain milk production equally as well as the amount proposed in the German standards. Woll deduces from the reports of one hundred and twenty-eight dairymen what he calls the American ration for dairy cows. In this standard 2.15 pounds of protein, or 0.35 less than the German standard, is advocated. Heacker of Minnesota maintains that rations made up of home-grown grains and furnishing 2 pounds of protein, or even less, will sustain milk production equally as well as do the nitrogenous feeding stuffs containing larger amounts of protein.

The feeding experiments of this Station, now under discussion, have heretofore been interpreted as indicating that the addition of protein to a ration not only sustains but stimulates milk production.

In Table 80 the rations are averaged to show the effect on milk flow of the addition of protein to the ration.

Upper division of the table.—Seven original rations fed to eighty-seven cows are compared with the recommended rations fed four weeks later. The protein in the original rations was in each case below 1.50 pounds; it averaged 1.40 pounds, and was increased to 2.09 pounds of protein in the recommended rations; the milk flow increased 0.83 pound following the change. It seems reasonable to assume, however, that a part of this increased milk flow was due to an increase of calories, which were below the standard, and to an increase of 1.37 pounds of grain in the ration.

Middle division, Table 80.—Seven herds of ninety-six cows received a large addition of protein in the recommended ration, although the amount fed in the original ration averaged as high as the recommended ration scheduled in the upper division; yet there was a falling off of 0.14 pound in milk flow.

Lower division, Table 80.—Seven herds of ninety-four cows received 0.17 pound more protein in the recommended than in the original rations, yet the increased milk flow is greater than in the middle division, where the increase in the protein was four times as great.

4. *The period of lactation. A more rational system of grain feeding.* As has been stated, the recommended rations were fed four weeks later than the original rations. The natural shrinkage in the milk flow under a uniform unchanged ration would theoretically amount to 0.85 pound per cow per day. In this connection it should be noticed, however, that the amount of grain received by each cow in each herd was not the same in the original and recommended rations. In the original rations the grain was generally apportioned to the individuals of the herd uniformly, although in some cases slightly more grain was fed to cows which were fresh, and less to those further along in lactation. In many of the recommended rations, however, grain was apportioned to the different individuals in the herd according to the milk production, or to the yield of total solids or butter fat. It seems reasonable to assume, therefore, that this more rational system of apportioning the grain in the recommended rations had a measurable effect on the milk flow, and that this in part at least offset the natural shrinkage that otherwise would have occurred.

CONCLUSION.

The twenty-one recommended rations were fed to the same herds four weeks later than the original rations. The average cow, instead of shrinking 0.85 pound daily as she normally would have done on a uniform ration, positively gained 0.25 pound, a total gain of 1.10 pounds of milk per cow per day. This increase in milk flow at 2½ cents per quart would amount to 1.29 cents per cow per day. There was an additional daily saving of 0.23 cent in food, while the value of obtainable manure was 0.5 cent greater, a total daily saving per cow of 2.02 cents as a result of the substitution of the recommended rations for the original. It seems reasonable to assume, however:

1. That part of this saving was due to an increase in the amount of grain fed.

2. That a decrease in calories in the recommended ration when they were above the standard in the original did not depress the ration, but, on the contrary, may have increased the effect of the ration.

3. The addition of protein to the ration shows to best advantage, as measured by increased milk flow, when the original rations carried less than 1.5 pounds of protein. But in these rations there is an increase of grain as well as of protein, and the increased milk flow of these cows may be attributed in part to the increase in grain.

4. An assumption that the calculated natural shrinkage in milk flow ordinarily occurring as the period of lactation advances under uniform unchanged rations was offset by the addition of protein to the recommended rations is not warranted. In Table 80, division C, seven herds of ninety-four cows received on an average only 0.17 pound increase in protein in the recommended rations. This small increase of protein is attended by the average milk flow. Division B, which received an increase of four times as much protein, made a greater shrinkage than did division C.

5. The food cost of the recommended rations is 0.23 cent less than the cost of the original rations. Ordinarily the addition of protein to a ration will increase the cost of the ration, as protein foods are the most expensive. The lessened cost of the recommended rations over the original is effected by feeding a smaller amount of nutrients. The 28,240 calories in the original rations cost 19.43 cents, or at the rate of 0.69 cent per 1,000 calories, while the 27,170 calories in the recommended rations cost 19.2 cents, or at the rate of 0.71 cent per 1,000 calories. If the excess of calories in the original rations (1,070) were not needed, the cost might have been reduced 0.74 cent (1,070 × .69) without affecting the milk flow. In this case the original rations would have cost a half cent less than the recommended ones.

6. The assumption does not seem to be warranted, therefore, that the food cost of a quart of milk was materially different in the original and recommended rations, although the latter contained more protein.

7. The net cost of a quart of milk was less with the recommended than with the original rations on account of the greater value of the estimated obtainable manure.

8. The teaching of this Station that rations containing more protein than those ordinarily fed to dairy cows are the more economical of the two, are on the whole warranted by the results obtained in the series of comparisons, and are therefore justified. Greater emphasis should be placed, however, upon the additional value of the manure obtainable from the more nitrogenous rations.

A SUCCESSFUL BROODER HOUSE.

BY F. H. STONEBURN.

No part of the equipment of a poultry farm is of greater importance than the arrangements for artificial brooding. The adult fowls, vigorous and well protected by nature, may survive and even thrive under adverse conditions, but the tiny chicks must have careful treatment.

Fig. 22. Brooder House.

The importance of the brooder house is emphasized when we consider that everyone engaged in commercial poultry keeping desires to produce a large proportion of his annual crop of chickens at some time of the year other than the natural breeding season of his fowls. This is true whether the main object be the production of meat or of eggs. Fall-hatched chicks are carried through the winter to be sold in the spring as roasters; winter-hatched chicks are marketed as early broilers; while the early spring-hatched stock is either marketed at the broiler age or carried to maturity to be used as breeders or egg producers.

The production of any large amount of this out-of-season stock by natural methods of rearing is, of course, out of the question, and the incubator and the brooder must be relied upon largely. The facilities for brooding the chicks vary according to the needs and resources of the different owners, ranging from a jug of hot water in a tight box to the huge pipe-system brooder houses found upon the leading poultry plants. But, unfortunately, in too many cases these brooding systems are inadequate, being poorly designed or improperly constructed. As a result the mortality among chicks entrusted to them is so excessive that it cuts down the profits very materially. In fact, observation leads one to believe that the greatest source of loss on the average poultry plant is to be found in the heavy mortality among chicks under two months of age.

A brooder building designed for the rearing of chicks during the cold months should embody several distinct features. For the health and well-being of the chicks it should be so constructed that the temperature and ventilation can be absolutely controlled, plenty of sunshine admitted, and enemies of all kinds kept out. For the comfort of the attendant and the economical conduct of the business it should be convenient in every way. Under this latter head are grouped many factors, because convenience in this case must include caring for the lamps and hovers, feeding and watering the chicks, managing the doors and windows, and keeping the house in a thoroughly sanitary condition. It is the object of this article to describe briefly a building which seems to embody most of the requirements enumerated above.

In the fall of 1903 the officers of the Connecticut Agricultural College decided to erect an additional brooder house at the college poultry plant, and plans prepared by the writer were approved. The structure was built during the fall and winter, and has been in constant use for several months. As this period has included both extremes of temperature, the test has been a fair one. The results have been very satisfactory.

Owing to the requirements of the poultry work of the College it was necessary that the building should be adapted to the purpose of instruction and experimental work, requirements which do not confront the person wishing to erect a house for practical purposes only. For several reasons it was decided

best to use small lamp brooders in each pen. This enables the attendant to manage each pen of chicks independently of the rest. For the above reason the plan should commend itself to those who are in the business on a comparatively small scale, as well as to the large operator who feels the need of a nursery brooder where the hover temperature can be regulated according to the needs of each pen of chicks.

The house as built is 15 x 30 feet in size, with a 4 x 5 feet extension on the east end. This latter is used as an entry or "ante-room," permitting students and others to pass in and out of the house at will during bad weather without exposing the chicks to draughts. An alley-way four feet in width extends along the entire north side, and the rest of the floor space is divided into pens. These are six in number and are 5 x 11 feet in size.

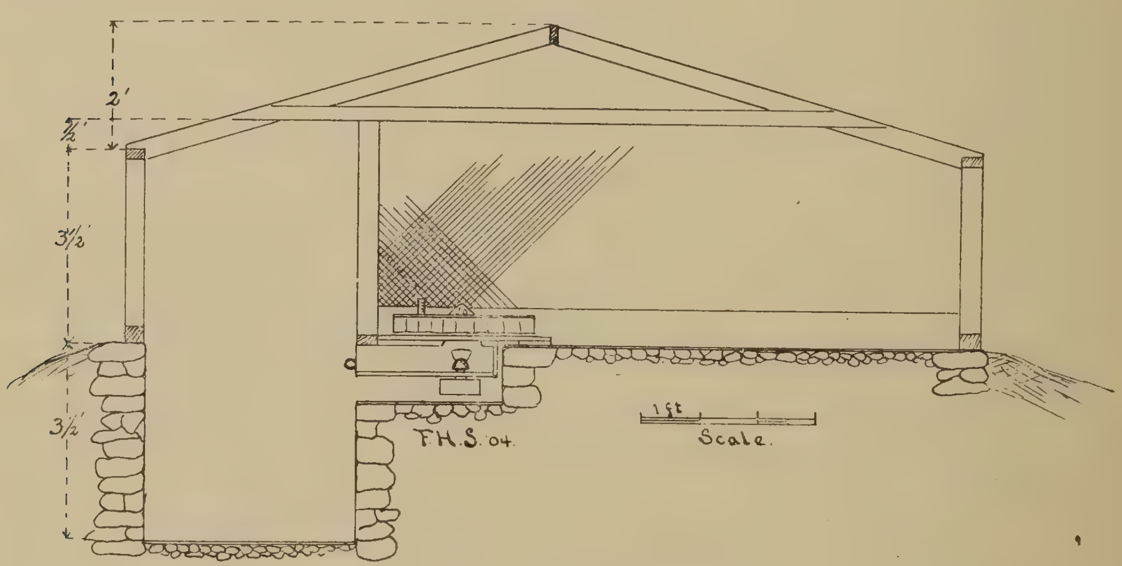


Fig. 23. Cross Section.

An examination of the accompanying cuts will show that the vital feature of the building is the elevated chick floor, or rather the depressed alley floor, the latter being 3½ feet below the former. This arrangement secures several advantages. It enables the attendant to care for the brooders and feed the chicks without the constant stooping required where the brooders are operated upon the floor in the usual manner. Further, it reduces the enclosed air space by fully one-third, effecting a corresponding saving in the amount of heat required to maintain a given temperature. It also places the chicks nearer the ceiling—the warmest part of the room—thus giving them the

benefit of all the available warmth. Repeated tests in the house under discussion demonstrated that in cold weather the temperature at the level of the alley floor is fourteen degrees lower than at the chick floor but 3½ feet above. And finally, the amount of side wall exposed to the weather is reduced nearly one-half, quite a consideration in wind-swept positions. The disadvantage of the plan becomes evident only when it is found necessary to enter the pens for any purpose. It is inconvenient because of the necessary climb to enter the pen and the confined space in which to do the work. But it has been found unnecessary to get into the pens except on rare occasions, so this is not a serious drawback.

The site selected for this house is a knoll sloping slightly to the north and abruptly to the east. The alley was formed by digging a trench of the required depth along the north side of the site of the proposed structure. Parallel stone walls 4 feet apart were then laid in this trench and carried to a height of 3½ feet. These were joined by a wall of the same height at the west end, the east end being reserved as a doorway. When laying the wall on the south side of the alley, provision was made for three lamp pits, each 2½ x 5 feet and 1 foot in depth as indicated upon the plans. Each pit accommodates the heaters of two brooders.

The rest of the foundation is a simple wall varying in height according to the slope of the land, but carried to the same level as the alley walls. Finally the entire floor was cemented, including the bottoms of the lamp pits, the cement in the chick pens being at the level of the top of the foundation walls.

Because of the small size of the building, the frame is constructed entirely of 2 x 4 inch material, except the sills, which are 4 x 4 inch. The walls are 3½ feet in height. The roof is an even span, with a rise of 2 feet. The rafters are tied with collar beams which are spiked on level 7½ feet from the alley floor. The entire frame is covered with ⅞ inch matched boards, with one-ply Flintkote upon the roof and Swan's extra heavy felt upon the sides. This gives an absolutely windproof structure. Eaves-troughs are required to carry from the roof the water which might otherwise make its way into the building.

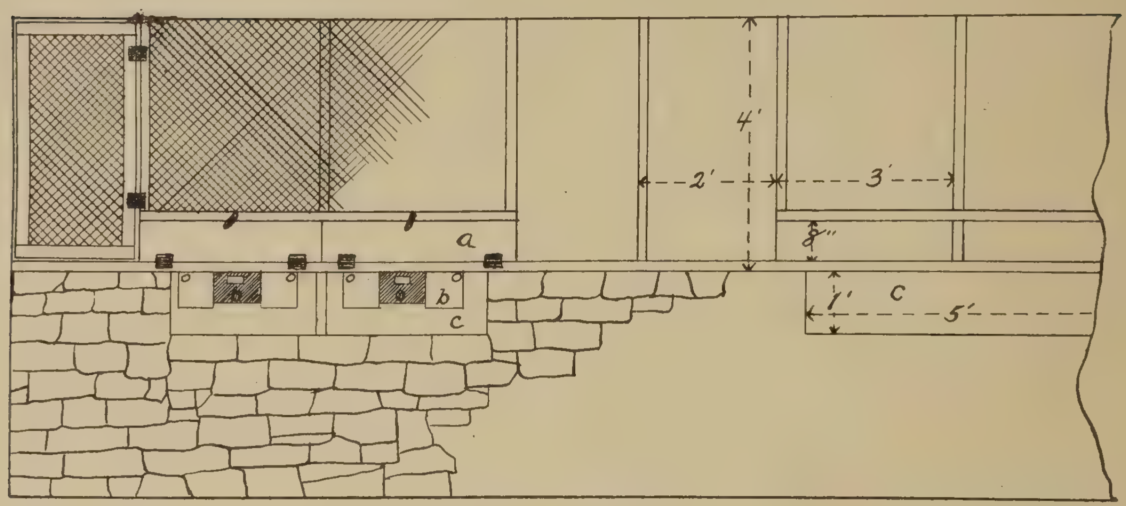


Fig. 24. Section showing south side of alley.

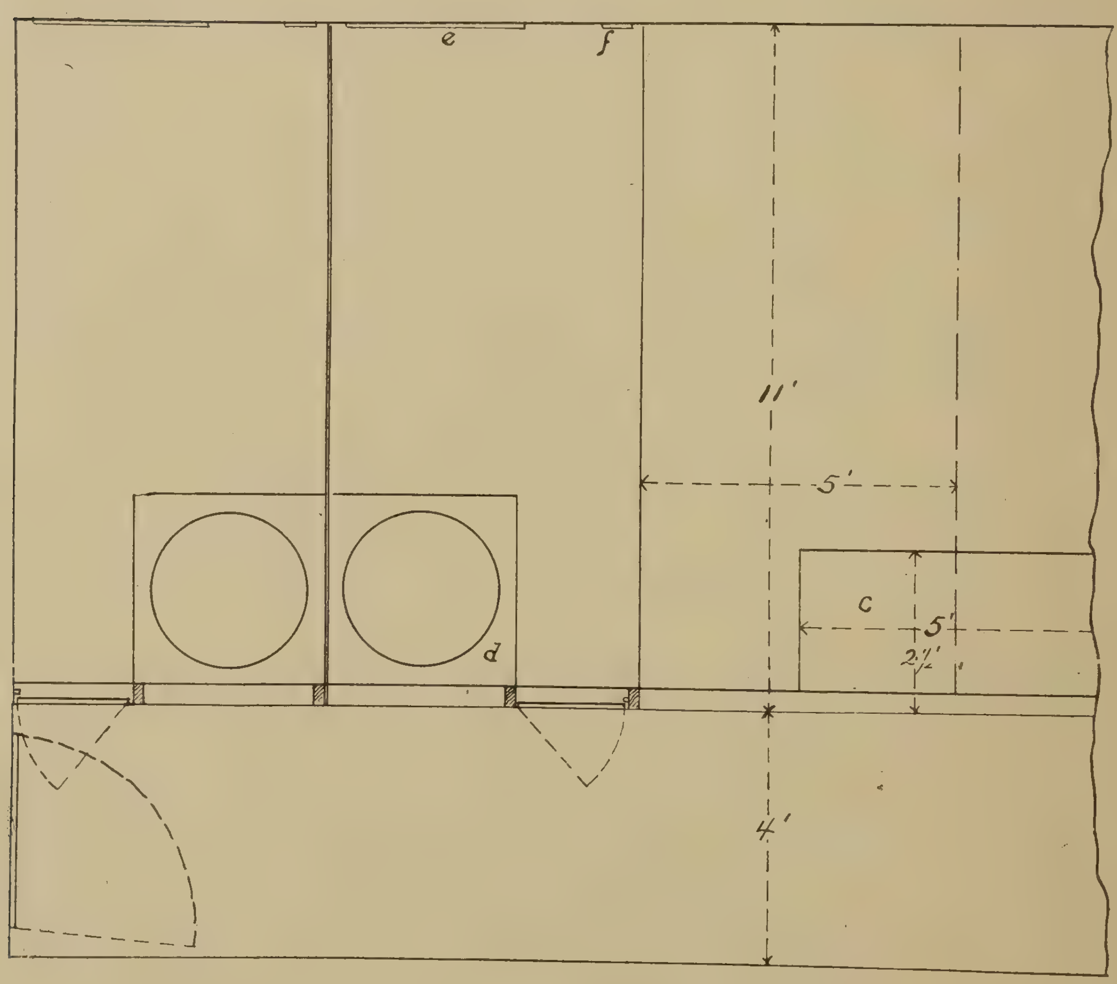


Fig. 25. Plan.

A.—Clean-out door, rear of brooder.
B.—Heater.
C.—Lamp pit.
D.—Brooder.
E.—Window.
F.—Chick door.

The interior is lathed and plastered with fire-proof asbestic plaster. By carrying the plaster across on the collar beams an attic is formed which is of great value in controlling the temperature, preventing direct radiation through the roof. A large sliding ventilator opens into this attic through the ceiling above each pair of chick pens, and in each gable doors are placed, opening into the attic from outside. These are regulated according to the weather. This forms a decidedly effective ventilating system which is entirely under control.

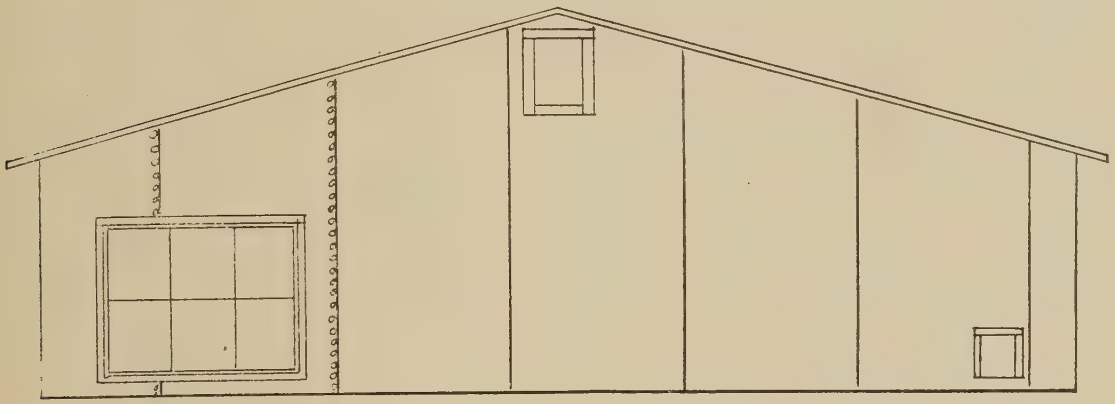


Fig. 26. West elevation.

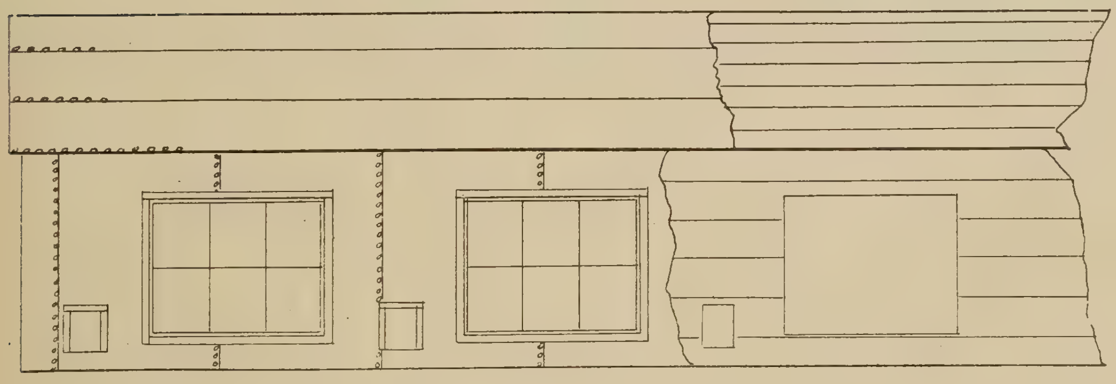


Fig. 27. South elevation.

In the south side of the building are six windows, one for each pen, each a single sash with six panes of 10x12-inch glass. These windows are hinged at the bottom, and swing inward, being controlled from the alley by cords. At the west end of the alley another window of the same size is placed. This lights the alley thoroughly, which is very desirable, particularly on dark, winter days. Chick doors are 6x7 inches in size, and are also operated by cords. The construction of

pen partitions is so fully illustrated by the cuts that no further explanation seems necessary. The door is made nearly as wide as the alley to permit the easy passage of wheelbarrows for cleaning.

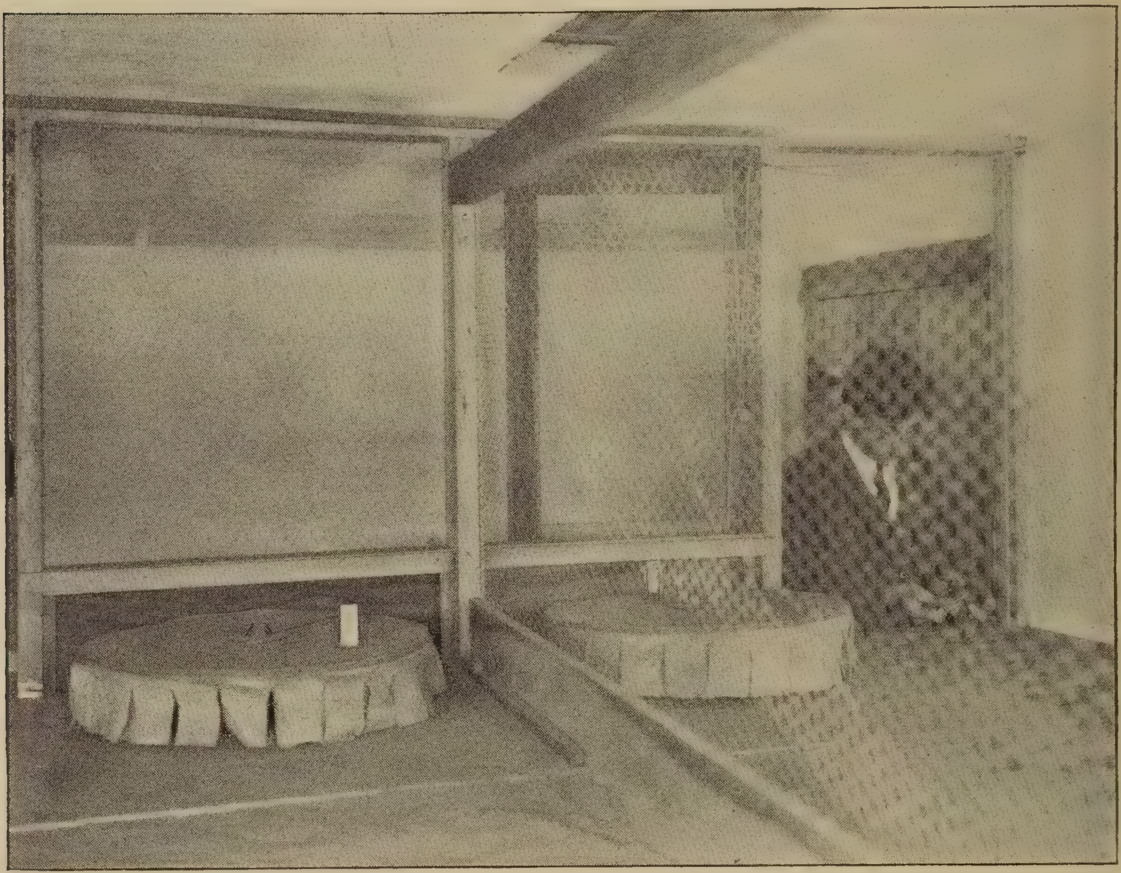


Fig. 28. Interior, showing two hovers.

The brooders were constructed by the college carpenter, using the metal parts of Peep o' Day brooders. They consist simply of the heaters and hovers mounted upon platforms, no sides or top being required. Because the heaters are suspended in the lamp pits, the floors of the brooders are elevated but two inches above the floors of the pens, which enables the chicks to enter the hovers without climbing the usual bridge. The pen floors are kept covered with one inch of sand and more or less fine litter, such as chaff, cut straw, etc. In ordinary weather the six lamps maintain the temperature sufficiently high, but an auxiliary heater is supplied for use in extreme cold. This is a stove placed near the west end of the alley, and a small fire in it will keep the building sufficiently warm at any time.

For the needs of the practical farmer or poultry man some slight changes might be made in the above plan. The alley could be reduced to three feet in width, and still be large enough to accommodate one attendant. The length of the chick pens might be reduced one or two feet, thus making the building narrower. The depth of the alley might be made three feet instead of three and one-half feet, and the sides made of heavy plank instead of masonry. The cement floor could be replaced with an earth floor, provided rats could be repelled. The entry extension could be dispensed with. For ordinary use in southern New England the wall might be satisfactory if constructed of two thicknesses of inch boards with paper between. All of the above changes would result in a financial saving so far as the first cost of the building is concerned, but, excepting the reduction in width of alley, they would also cause a decreased efficiency.

EXPERIMENTS ON THE DIGESTIBILITY OF CEREAL BREAKFAST FOODS.

REPORTED BY W. O. ATWATER.*

It has been frequently set forth in publications of this Station that in estimating the nutritive value of any food material, a very important consideration is its digestibility or availability. (See page 187). It is necessary to take into account not only the chemical composition of the material, that is the amount of the different nutritive ingredients it contains, but also the proportion of each that will be digested and made available to the body for the purposes of nutrition—the building of tissue and the yielding of energy. Two food materials may be very much alike in chemical composition and yet differ materially in actual nutritive value because of differences in digestibility. For example, it has been found that when coarse graham and fine white flours are milled from the same lot of wheat the composition of the two is much the same, there being a little more protein in the graham than in the white flour; but the digestibility of the bread from the fine flour is so much greater than that from the coarse flour that the body actually obtains more nourishment from a given quantity of the fine flour than from the same quantity of the coarse flour.

Considerable is now known concerning the digestibility or availability of mixed diet in general, and to some extent of different classes of food materials in particular. Much work of this nature still remains to be done, however, and the need for it is urgent. In view of the importance of knowledge concerning the availability of different food materials, much attention

*Dr. H. C. Sherman and Mr. R. D. Milner were responsible for carrying out the details of these experiments. Mr. Milner also had charge of the analytical work and the calculation and tabulation of the results, and assisted in preparing this report.

is given to this subject in connection with the nutrition investigations carried on by the Storrs Station, in coöperation with the U. S. Department of Agriculture.*

One important class of food materials that is being used to an increasing extent in the ordinary diet of families is that of cereal breakfast foods. The chemical composition of the large number of various kinds of such foods now on the market is quite well known, the analyses being already very numerous; but little has hitherto been definitely understood regarding the availability of these foods to man. During the past year a series of digestion experiments with breakfast foods was carried on as part of the nutrition investigations of the Storrs Station. An account of these experiments, and the results obtained, is given in the present article.

DETAILS OF EXPERIMENTS.

The work here reported comprises nine experiments with three different brands of breakfast foods; three with "Grape-Nuts," four with "Malta Vita," and two with "Force." Each of these materials was eaten, in separate experiments, in a very simple diet consisting only of milk, cream and sugar in addition to the cereal. All the food consumed and feces excreted were carefully weighed and sampled and the samples analyzed. From these data for amounts and composition of food and

---

*Previous reports of the Station have contained accounts of nutrition investigations carried on in coöperation with the U. S. Department of Agriculture. This coöperative inquiry regarding the food and nutrition of man is provided for by an Act of Congress which makes an appropriation of $20,000 per year for the purpose. The responsibility for the inquiry is intrusted to the Secretary of Agriculture, who places the immediate charge in the hands of the writer. It has been the definite policy of the Department to invite the coöperation of a considerable number of investigators and institutions in different parts of the United States in the prosecution of this inquiry. The share borne by the Storrs Experiment Station consisted in several kinds of work, of which some of the principal features have been metabolism experiments with the respiration calorimeter, digestion experiments with different kinds of food materials and studies of actual dietaries of people of different classes. The work of the year 1903 included a continuation of the investigations with the respiration calorimeter and a number of digestion experiments in which the nutritive values of several different kinds of food materials were tested by actual experiments with healthy men. Among the food materials tested were several of the breakfast foods which are in common use in Connecticut and elsewhere. The results of these latter investigations are reported in the present article.

Investigations with breakfast foods, similar to those here reported and like these forming part of the coöperative inquiry mentioned above, have also been made during the past year at the Maine and Minnesota Stations. It is probable that the results of all these investigations will be included in a publication of the Department of Agriculture.

feces the availability of the diet as a whole and of the cereal portion of the diet alone was calculated, as explained more fully hereafter. The details of the experiments are given in the paragraphs which follow.

List of experiments.—A list of the experiments, showing the subject, date, duration, and kind of cereal food in each, is given in the following table.

TABLE 81.

List of digestion experiments.

Subjects.			Experiments.			
Initials.	Age.	Weight.	Number.	Date.	Duration.	Cereal.
	Years.	Lbs.		1903.	Days.	
E. O.,	38	155	560	June 24–27,	4	Grape-Nuts.
			564	July 2–5,	4	Malta Vita.
			566	July 6–8,	3	Force.
A. B. A.,	25	155	558	June 24–26,	3	Grape-Nuts.
R. D. M.,	34	165	559	June 24–27,	4	Grape-Nuts.
			562	July 2–5.	4	Malta Vita.
H. C. S.,	28	145	561	July 2–5,	4	Malta Vita.
			565	July 6–8,	3	Force.
J. A. R.,	20	140	563	July 2–4,	3	Malta Vita.

Subjects.— The subjects of the experiments were five young men in good physical condition and with apparently normal digestion and nutrition. Three of them, E. O., H. C. S., and R. D. M., had previously been subjects of digestion experiments, and the other two, as a result of their experience in the laboratory, fully understood the nature and requirements of such experiments.

Occupation.—All of the subjects of the digestion experiments were engaged in light work in connection with the nutrition investigations, and each one took some physical exercise each day. The total daily amount of muscular activity might probably be on the average about equivalent to that of a man at light muscular work. No attempt was made, however, to prescribe a uniform amount of exercise for each subject from day to day. The men simply pursued their ordinary course of life except as regards diet.

Duration.—In general, the longer the digestion experiment the more reliable the results, because errors such as might occur from failure to obtain complete separation of the feces for the digestion period would thus be proportionally smaller. It was desired to have each of these experiments continue not less than three days, and preferably four days. Five of the experiments continued part or all of the fourth day, and the other four terminated with the end of the third day, as explained beyond.

Diet.—The diet in these experiments consisted of the breakfast food with milk and cream and a little sugar. No restriction was placed upon the amount of any food material to be eaten, each subject choosing what seemed to him to be sufficient to satisfy his needs. Some of the subjects, however, endeavored to have the cereal portion, at least, of the different meals somewhat uniform in amount.

The diet was purposely made as simple as possible consistent with palatability, in order that the availability of the cereal portion alone might be computed, as hereafter explained. Theoretically, an ideal diet for investigations of this nature would consist of only the material studied; but experiments with men on a single food material are not practicable, for several reasons. In the first place, the very monotony of the diet might prove an objection, because for subjects accustomed to a varied diet a ration of but one food material commonly becomes decidedly unpalatable after a few meals, so that it cannot be eaten for as many days as desired for satisfactory experiment. In the second place, the availability of a given food material when eaten alone appears to be not the same as when eaten with other materials. In experiments with bread and milk, for instance, when the ration contained both materials the availability was greater than when either material was eaten alone. In fact the nutrients of the simple diet of bread and milk were about as completely available as those of a more varied diet.

In view of these facts, in order to increase both the palatability and the availability of the ration over that of one consisting of the cereal food alone, it was deemed best to include the other foods mentioned above with the breakfast food.

Moreover, these cereal foods are commonly eaten with sugar and milk or cream, hence it seemed the more appropriate to eat them in this way in these experiments.

It might be objected that, since cereal breakfast foods as a rule are eaten with only one meal of the day, and frequently form but a small part of the total ration, experiments in which they are eaten as a considerable part of each meal for three meals a day would not give reliable results regarding their availability because the conditions would be unusual. That is, it could not be definitely stated that the availability as thus determined would be the same as for the same material eaten under the usual conditions, as part of a mixed diet. It has been pointed out that a simple diet of bread and milk has been found to be about as completely utilized as a more varied ration. It may also be stated that a number of experiments have been made, in this country and in Europe, in which the diet has become exceedingly monotonous, and was eaten only with difficulty, yet the digestion of the food was not affected, and the coefficients of availability were found to be practically the same as those for more varied rations under normal conditions. It is therefore believed that the results obtained in the series of experiments here reported are reliable.

Description of food materials.—For these experiments three breakfast foods in very common use were chosen. All three were claimed by their makers to have wheat as a basis, though combined with other materials. The goods were bought from a local grocer, in the sealed packages in which they were sent from the factory. In each case the material obtained was believed to be representative of goods of the same brand sold in other markets.

"Force," prepared by the Force Food Co., of Buffalo, N. Y., is claimed by the manufacturers to contain "the whole of the wheat scientifically combined with barley malt."

"Malta Vita," manufactured by the Pure Food Co., of Battle Creek, Mich., is also claimed to be a preparation of wheat and barley malt. It closely resembles "Force" in appearance and general character.

"Grape-Nuts," manufactured by the Postum Cereal Co., of Battle Creek, Mich., is claimed to be a combination of wheat and barley, prepared by special treatment.

The milk used in the experiments was from a mixture of the total product of several cows of a local herd, milk from the same cows being included each day. Previous experience had shown that the milk thus obtained was quite uniform in composition from day to day.

The cream used was that obtained by use of a separator from the mixed milk from a considerable number of cows.

The sugar was granulated cane sugar obtained from a local grocer.

Sampling of food.—The subjects of the digestion experiments ate together in the laboratory, taking three meals daily at the usual hours. Each one weighed his own food just before eating. Before the experiments began, a quantity of the given breakfast food, more than sufficient for all the needs of the experiments, was thoroughly mixed, and from the mixed material a sample taken for analysis. The rest was then kept in a large air tight receptacle, from which the subjects took the desired amount for each meal. In this way one analysis of a given breakfast food served for all the experiments with that particular food.

Milk and cream were delivered at the laboratory in bottles, fresh each morning. As soon as the milk was delivered it was all poured into a large jar and thoroughly mixed, and from this an aliquot portion was then taken for a sample, the samples for all the days of an experiment being mixed together to form a composite sample for analysis. The cream was treated in the same manner. Each of the subjects at meal time took his portion of milk or cream from the large jar, being careful to mix thoroughly each time, so as to distribute the fat evenly.

No sample was taken of the granulated sugar, since this material has been found so uniform in composition that analysis was deemed unnecessary.

Separation of feces.—The success of a digestion experiment depends very largely upon the satisfactory separation of the feces of the experiment from those of the food immediately preceding and following. Separation was effected in these experiments by means of lampblack in gelatin capsules, each subject taking one capsule with the first meal of each experiment, and another with the first meal succeeding each experiment. All the feces colored by the first capsule were included in the

experiment, and those colored by the second capsule were excluded. The feces were deposited by each subject upon a shallow tray in such a way as to facilitate separation. In most cases the separations were quite satisfactory, though in some instances, where the cereal had a laxative effect, the point where the discoloration began in the final separation of an experiment was not as sharply defined as desirable.

The total amount of feces for an experiment for each subject was dried and ground for analysis.

Analysis of food and feces.—Analysis of the food materials and feces were made according to the methods adopted by the Association of Official Agricultural Chemists.* The heats of combustion were made by means of the bomb calorimeter.† The

TABLE 82.

Percentage composition and heats of combustion of foods and feces in digestion experiments Nos. 558–566.

Lab. No.	KIND OF MATERIAL.	Water.	Protein.‡	Fat.	Carbohydrates.	Ash.	Heat of combustion per gram.
		%	%	%	%	%	Cals.§
3671	Grape-Nuts,	6.47	11.63	.77	78.96	2.17	4.061
3677	Malta Vita,	11.32	12.20	1.52	72.03	2.93	3.841
3684	Force,	10.86	9.86	1.65	74.77	2.86	3.822
3672	Milk,	86.04	3.31	4.71	5.29	.65	.799
3678	Milk,	86.23	3.19	4.79	5.17	.62	.808
3685	Milk,	86.55	3.13	4.30	5.41	.61	.762
3673	Cream,	71.97	2.81	21.58	3.10	.54	2.240
3679	Cream,	73.05	2.56	20.45	3.41	.53	2.418
3686	Cream,	72.73	2.38	21.00	3.42	.47	2.269
—	Cane sugar,	—	—	—	100.00	—	3.960
3674	Feces (partially dried),	6.11	20.63	15.92	40.79	16.55	5.040
3675	Feces (partially dried),	7.16	23.69	13.79	41.71	13.65	4.940
3676	Feces (partially dried),	5.11	20.75	16.02	42.37	15.75	5.462
3680	Feces (partially dried),	6.60	21.06	10.65	43.89	17.80	4.644
3681	Feces (partially dried),	7.22	22.00	14.41	42.03	14.34	4.824
3682	Feces (partially dried),	6.33	22.00	12.00	45.51	14.16	4.824
3683	Feces (partially dried),	6.59	19.63	16.08	42.38	15.32	4.802
3687	Feces (partially dried),	6.41	19.38	7.56	47.94	18.71	4.523
3688	Feces (partially dried),	5.14	17.00	33.65	27.77	16.44	5.633

* U. S. Dept. Agr., Division of Chemistry, Bul. 46, revised.

† Jour. Amer. Chem. Soc., Vol. 25, No. 7 (1903), p. 659.

‡ For cereals, N × 5.70; for milk, cream and feces, N × 6.25.

§ The unit of energy throughout this article is the large Calorie, i. e., the quantity of heat necessary to raise 1 kilogram of water 1 degree Centigrade.

composition and heats of combustion of the materials are given in the following table. It will be observed that the figures for the feces are those for the material in the partially dried condition in which it was analyzed. Inasmuch as the total quantity of water in the feces is not considered in a digestion experiment, it seemed unnecessary to reduce the figures from those for the partially dried to those for the fresh material, since the calculation of the ingredients in the feces may be made in the same way, by use of the figures here given, and the total weight of partially dried feces.

CALCULATION OF RESULTS.

The data of the digestion experiments are given in Tables 84 to 86 beyond. The first column in each table shows the total quantity of each food material consumed, and of feces excreted (except that the weight of feces is that of partially dried rather than fresh material), and the third and succeeding columns the quantities of nutrients and energy contained in the food and feces as calculated from the figures in the first column and those in Table 82. The second column shows the quantity of total organic matter in the food and the feces, as found by adding the quantities of protein, fats and carbohydrates. From the figures for the quantity of each nutrient in the food and in the feces the digestibility or availability of the nutrients in the total diet and in the cereal portion alone are computed, according to the method here described.

Digestibility or availability of total diet.—In the case of the diet as a whole, the computation of what is commonly considered the digestibility of the nutrients is a comparatively simple matter. The difference between the quantity of each nutrient in the total food and the amount of the corresponding ingredient in the feces is taken as the quantity of the given nutrient digested. Dividing the amount digested by the total amount in the food eaten, and multiplying by 100, gives the percentage of the given nutrient digested; or, as it is generally called, its coefficient of digestibility.

Strictly speaking, the results thus obtained do not represent actual or true digestibility, for the reason that the feces contain not only the portions of food that are not digested, but also

other materials, which comprise what are commonly designated as metabolic products. These consist largely of the residues of digestive juices poured into the alimentary canal and not reabsorbed, but contain also more or less of true excretory products. To determine actual digestibility it would be necessary to separate these metabolic products from the actually undigested food, and deduct the ingredients of the latter from those of the food eaten. Thus far, however, no satisfactory method for separating the undigested residues from the metabolic products of the feces has been devised, consequently the actual digestibility of the food is not easily determined. Obviously the result obtained as explained above, and designated digestibility, is somewhat below the true digestibility.

On the other hand, the metabolic products may be considered as representing the cost of digestion in terms of food ingredients, and the total feces, including both these and the actually undigested residue of the food, may be taken as representing the portion of the food that is not available to the body for purposes other than digestion—the building of tissue and the yielding of energy. The difference between the amount of each ingredient in the total food and that in the total feces may, therefore, be designated as the availability, rather than the digestibility, of the ingredient. In the present discussion the term availability is therefore used to indicate what is frequently designated digestibility.

While the above method of computation shows the amount of the different nutrients that are available to the body, the corresponding computation for energy represents the quantity of energy in the food absorbed from the alimentary canal, and not the amount which the body actually utilizes, because a portion of the absorbed material is not completely burned in the body. The absorbed carbohydrates and fats are believed to be completely oxidized, but the protein is not. When protein is burned in the bomb calorimeter, the carbon is oxidized to carbon dioxid, and the hydrogen to water, the nitrogen being reduced to the free state; but when burned in the body, the oxidation is less complete, the nitrogen, together with some carbon, hydrogen and oxygen, being excreted in such compounds as urea, uric acid, etc., that are capable of further oxidation

outside the body. In computing the quantity of energy available to the body, account must therefore be taken of the energy of these incompletely oxidized residual products of protein, which are excreted in the urine.

Two methods of estimating the amounts of energy, for which such allowance must be made, are common. In one case, the total amount of urine for the experimental period is collected, and the heat of combustion of the organic matter in it is determined. This period is not chosen with the idea that the nitrogen of the urine, thus collected, represents the actual protein katabolism of the food under investigation; but in the absence of any means of marking the urine for a given period, similar to that followed in the case of the feces, and in lack of definite knowledge concerning the nitrogen lag, that is, the time between the ingestion of nitrogen in the food and its excretion in the urine, the period of the experiment is most convenient. The chief uncertainty of this method is in the impossibility of tracing any exact relation between the protein of the food eaten on a given day and the nitrogen of the urine.

In the other case the energy lost in the urine is computed. Since urea is the most abundant of the organic materials in (normal) urine, it has sometimes been assumed that all the nitrogen from the katabolism of protein is excreted in this substance, and allowance made for the heat of combustion of an amount of urea corresponding to the amount of nitrogen in the urine. According to such an assumption, 0.87 calorie* of the energy latent in each gram of available protein would be lost to the body in the urea formed from the nitrogen of the protein. In a considerable number of experiments made at this Station, however, it has been found that the average heat of combustion of the organic matter of the urine corresponding to 1 gram of available protein amounts to 1.25 calories.† It is believed that the energy of urine as calculated by use of this factor, derived from a relatively large number of determinations in experiments extending over considerable periods, so that the error due to nitrogen lag would be very appreciably diminished if not altogether eliminated, is reasonably accurate.

* U. S. Dept. Agr., Office of Experiment Stations, Bul. 44, p. 40.

† Storrs Expt. Sta. Rpt. 1899, p. 100.

In the present experiments it was not convenient to collect the urine and make determinations of the heat of combustion of the organic matter, consequently the amount of energy lost to the body because of incomplete oxidation of the protein was computed by multiplying the amount of available protein by the factor 1.25. Deducting this quantity of energy from the energy of the material absorbed from the alimentary canal gives the quantity of energy utilized by the body, which is here considered as the available energy; and dividing this by the total energy of the food, and multiplying by 100, gives the percentage of total energy available, or the coefficient of availability of the energy.

The computation of the available energy of the total diet in experiment No. 558 would therefore be as follows: The total energy of the food, 11,464 calories, less the energy of the feces, 787 calories, gives the energy of the food absorbed from the alimentary canal, 10,677 calories. The quantity of available protein of the total food, 223.7 grams, multiplied by the factor 1.25, gives the energy of the material in the urine, 280 calories. The energy of the material absorbed, 10,677 calories, less the energy lost in the urine, 280 calories, gives the energy actually available to the body, 10,397 calories, and this result divided by the quantity of energy in the total food, 11,464 calories, and multiplied by 100, gives 90.69 per cent. as the coefficient of availability of the energy of the total food.

Availability of cereal portion of the diet.— As previously stated, the diet of the experiments was made very simple in order that the availability of the cereal portion alone might be computed. For this purpose, all the other materials except the cereal (i. e. milk, cream and sugar) were those of which the availability of the nutrients was quite well known from the results of previous experiments, and it was assumed that the averages of such results would represent the availability of the nutrients of such materials in the present experiments. By use of these factors it is possible to compute how much of the feces should pertain to the part of the diet that was not cereal, and the rest may be ascribed to the breakfast food. From these results, and the amounts of nutrients in the breakfast food eaten, the availability of the nutrients of the cereal alone may be estimated in the same way as explained above for total diet.

In making these computations it was assumed that 97 per cent. of the protein and 95 per cent. of the fat of milk and cream, and 98 per cent. of the carbohydrates of milk, cream and sugar, would be available;* or in other words, that 3 per cent. of the protein and 5 per cent. of the fat of milk or cream, and 2 per cent. of the carbohydrates of milk, cream and sugar were not available and should be accounted for in the feces. The method of computing the availability may be explained by use of figures from one of the experiments.

Data from experiment No. 558 (Table 84) are here taken for illustration. In this case the total amount of protein supplied by milk and cream was 166.3 grams, of which 97 per cent. was assumed to be available, leaving 3 per cent. to be found in the feces, or ($166.3 \times .03 =$) 4.99 grams. The total amount of protein in the feces from the whole diet was 32.20 grams†, and the difference between this and the amount computed as due to milk and cream, ($32.20 - 4.99 =$) 27.21 grams, was assumed to be due to the cereal part of the diet. Dividing the latter quantity by 89.55 grams, the total protein supplied by the cereal, and multiplying by 100, gives 69.62 per cent. as the coefficient of availability of the protein of the cereal alone. The coefficients for the other nutrients are calculated in the same way.

It will be observed, however, that the results of the computations for fat in the breakfast foods are not given. The reason is that the quantity of fat in cereals is so small that a slight error in the assumed factor for availability of fat in the rest of the diet makes a large difference in the computed coefficient for the fat of the cereal alone.

The computation of the available energy of the cereal is likewise simple, being practically the same as that for total diet previously explained. The data consist of the total energy of the cereal, the energy of the feces due to cereal alone, and the energy lost in the urine from incomplete oxidation of the protein of the cereal. In the case of the total diet, the energy of the food and that of the feces was found by use of the bomb calorimeter. This is true of course for the energy of the cereal

* Storrs Expt. Sta. Rpt., 1899, p. 86.

† For strict accuracy, the protein of total feces, computed by multiplying the nitrogen in total feces by 6.25, should be taken as the sum of the protein of feces from food other than cereal ($N \times 6.25$) and of the protein of feces from cereals ($N \times 5.7$). This change would slightly increase the coefficients of availability of protein and carbohydrates in the cereal alone over the results given in Table 87.

portion of the diet, but obviously there are no such actual determinations for the portion of the feces due to cereal. The energy in this case is found by subtracting from the energy of total feces the computed energy of the part of the feces ascribed to food other than cereal. The energy lost in the urine is found for the cereal alone in the same manner as for the total diet, namely, by multiplying the available protein of the cereal by the factor 1.25.

The energy of the part of the feces estimated to be due to food other than cereal was calculated from the amount of protein, fat and carbohydrates in it. Previous investigations* have shown that the heats of combustion of the nutrients in an ordinary mixed diet average per gram as follows: for protein, 5.65 calories, for fat 9.4 calories, and for carbohydrates 4.15 calories. In lack of any corresponding factors for the ingredients of feces, these values were used. But the heat of combustion of the total feces as calculated by the use of these factors varies somewhat from the heat of combustion as actually determined; and it seems reasonable to suppose that there would be a corresponding variation between the computed heat of combustion of the feces from food other than cereal and the actual determination if such could be made. In computing the energy of this part of the feces, therefore, it was assumed that the ratio of the computed heat of combustion of the total feces to the heat of combustion as actually determined was the same as the ratio of the computed heats of combustion of the feces from food other than cereal to the actual values.

For example: in experiment No. 558 (Table 84, p. 196), the computed heat of combustion of the total feces was 680 calories, whereas the value as actually determined by the bomb calorimeter was 787 calories. The computed heat of combustion of the part of the feces pertaining to food other than cereal was 350 calories; and the actual heat of combustion was therefore assumed to be the fourth term in the proportion $680:787 = 350:x$, in which case $x = 406$ calories.

This figure being obtained, the next step is to find the energy of feces from cereal alone, by subtracting this quantity from the determined heat of combustion of the total feces, which gives $(787 - 406 =)$ 381 calories. The proportion of energy in the

*Storrs Expt. Sta. Rpt. 1899, p. 104.

cereal alone which was actually available (85.32 per cent.) is then obtained by subtracting from the total energy in the cereal (3,127 calories) the estimated energy in the feces from the cereal (381 calories) and the energy lost in the urine (62.34 — 1.25 =) 78.0 calories, and dividing this result by the total energy in the cereal consumed (3,127 calories).

DATA OF THE EXPERIMENTS.

In these experiments no attempt was made to have the quantities of the different food materials the same for all the subjects, nor even for the same subject from meal to meal. Each subject ate according to his appetite at each meal, weighing his own food from the same lot as the others, just before eating. The weighings were made on a sensitive torsion balance, and one subject checked the weights taken by another, to insure accuracy.

Some of the subjects, from choice, endeavored to maintain the total quantity of the cereal per day the same throughout an experiment, and in some cases the quantity per meal was uniform for a given day. In the case of the milk and cream there was in general less uniformity in amount, though in at least one case this was the same for each meal of the whole experiment. Each subject poured some milk or cream into a vessel, used what he wanted at the meal, and determined the amount from the weight of the vessel and contents at the beginning and end of the meal. Sugar was treated in the same way, except that the weight of the bottle and the sugar was taken at the beginning and end of the experiment, so that the quantity eaten per meal or per day is not known.

The total quantity of each food material eaten in the different experiments is shown in the table below. The last column shows the average quantities per day; but it will be observed, from what is explained above, that these do not, in some cases, show the amount that was actually eaten per day. These latter figures are given for the cereal part of the diet in connection with the data of the experiment beyond.

TABLE 83.

Data regarding kinds and amounts of food eaten in digestion experiments Nos. 558–566.

Experiment No.	SUBJECT.	Date.	Duration, days.	Kind of food.	AMOUNTS EATEN. Whole experiment.	AMOUNTS EATEN. Average per day.
				Grape-Nuts experiments.	Grams.	Grams.
558	A. B. A., -	1903. June 24–26,	3	Grape-Nuts,	770.0	257.0
				Milk,	3,309.0	1,103.0
				Cream,	2,022.0	674.0
				Sugar,	294.0	98.0
559	R. D. M., -	June 24–27,	4	Grape-Nuts,	1,050.0	262.5
				Milk,	3,484.8	871.2
				Cream,	2,224.5	556.1
				Sugar,	294.8	73.7
560	E. O., -	June 24–27,	4	Grape-Nuts,	800.0	200.0
				Milk,	3,919.8	979.9
				Cream,	2,470.0	617.5
				Sugar,	219.6	54.9
				Malta Vita experiments.		
561	H. C. S., -	July 2–5,	4	Malta Vita,	1,200.0	300.0
				Milk,	7,580.0	1,895.0
				Cream,	580.0	145.0
				Sugar,	45.0	11.3
562	R. D. M., -	July 2–5,	4	Malta Vita,	1,205.0	301.3
				Milk,	3,753.6	938.4
				Cream,	2,495.3	623.8
				Sugar,	348.5	87.1
563	J. A. R., -	July 2–4,	3	Malta Vita,	923.0	307.7
				Milk,	3,214.8	1,071.6
				Cream,	1,469.2	489.7
				Sugar,	226.5	75.5
564	E. O., -	July 2–5,	4	Malta Vita,	1,200.0	300.0
				Milk,	5,470.1	1,367.5
				Cream,	3,017.1	754.3
				Sugar,	191.6	47.9
				Force experiments.		
565	H. C. S., -	July 6–8,	3	Force,	900.0	300.0
				Milk,	5,960.0	1,986.7
				Cream,	160.0	53.3
				Sugar,	28.5	9.5
566	E. O., -	July 6–8,	3	Force,	600.0	200.0
				Milk,	4,000.0	1,333.3
				Cream,	500.0	166.7
				Sugar,	122.0	40.7

EXPERIMENTS WITH GRAPE-NUTS.

Experiments with Grape-Nuts were made with three subjects. The experiments with A. B. A. and R. D. M. began with breakfast, and that with E. O. with dinner of June 24, 1903. The experiment with A. B. A. continued three days, with nine meals, and those with R. D. M. and E. O. each four days, with eleven meals. A. B. A. ate 120 grams of the cereal with the first meal, 100 grams with each of the next five meals and 50 grams each with the remaining three meals; R. D. M. ate 100 grams each with ten meals and 50 grams with the last meal; E. O. ate 100 grams each with the first five meals, and 50 grams each with the remaining six meals. The quantities of the other materials eaten were less uniform.

The data of these three experiments are given in Table 84 beyond.

With all three subjects the diet became decidedly disagreeable before the experiment ended. There was considerable fermentation in the alimentary tract, accompanied by apparent irritation of the intestine, and more or less pain, which, with one of the subjects, A. B. A., was so severe on the third day that he had to terminate the experiment sooner than was intended, though he managed to complete three full days before taking the second capsule of lampblack. R. D. M. continued two meals longer, but had to reduce the quantity of cereal eaten, and was unable to take the last meal on the fourth day because of the decidedly uncomfortable conditions of the intestine, and also because the cereal had become very distasteful, so that the last meal was eaten only with difficulty. E. O. managed to continue until supper of the fourth day, but at the beginning of the third day he had greatly reduced the quantity of cereal eaten.

The experiments were carried on during the warm summer weather, and it may be that the condition of temperature was favorable to the presence and growth in the cereal of some of the organisms that cause fermentation in the alimentary tract. It is possible that the relatively large amounts of cream eaten in some instances might have had some influence in creating the intestinal disturbances, though it is believed that it had none, because all of the subjects were fond of cream, and at

TABLE 84.—*Results of digestion experiments with "Grape-Nuts," Nos. 558, 559 and 560.*

Kinds of food:—Grape-Nuts, milk, cream and sugar.
Subjects:—A. B. A., R. D. M., E. O.

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 558, with A. B. A. (Duration 3 days.)	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
	Food eaten:							
3671	Grape-Nuts,	770	703.47	89.55	5.93	607.99	16.71	3127
3672	Milk,	3309	440.43	109.53	155.85	175.05	21.51	2644
3673	Cream,	2022	555.85	56.82	436.35	62.68	10.92	4529
	Sugar,	294	294.00	—	—	294.00	—	1164
	Total,	6395	1993.75	255.90	598.13	1139.72	49.14	11464
3674	Feces, from total food,	156.1	120.72	32.20	24.85	63.67	25.83	787
	Feces,* from food other than Grape-Nuts,	—	—	4.99	29.61	10.63	—	406
	Feces,* from Grape-Nuts alone,	—	—	27.21	—	53.04	—	381
	Amount digested from total food,	6238.9	1873.03	223.70	573.28	1076.05	23.31	10677
	Amount* digested from Grape-Nuts alone,	—	—	62.34	—	554.95	—	—
	Energy of urine from total food,†	—	—	—	—	—	—	280
	Energy of urine from Grape-Nuts alone,†	—	—	—	—	—	—	78
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food,	—	93.95	87.42	95.85	94.41	47.44	90.69
	Of Grape-Nuts alone,	—	89.27	69.62	—	91.28	—	85.32
	Experiment No. 559, with R. D. M. (Duration 4 days.)							
3671	Food eaten:	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
3672	Grape-Nuts,	1050.0	959.29	122.12	8.09	829.08	22.79	4264
3673	Milk,	3484.8	463.83	115.35	164.13	184.35	22.65	2784
	Cream,	2224.5	611.52	62.51	480.05	68.96	12.01	4983
	Sugar,	294.8	294.80	—	—	294.80	—	1167
	Total,	7054.1	2329.44	299.98	652.27	1377.19	57.45	13198
3675	Feces, from total food,	188.2	149.03	44.58	25.95	78.50	25.69	930
	Feces,* from food other than Grape-Nuts,	—	—	5.34	32.21	10.96	—	428

TABLE 84.—*Continued.*

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 559, Con.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
	Feces,* from Grape-Nuts alone, - - - -	—	—	39.24	—	67.54	—	502
	Amount digested from total food, - - - -	6865.9	2180.41	255.40	626.32	1298.69	31.76	12268
	Amount* digested from Grape-Nuts alone, -	—	—	82.88	—	761.54	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	319
	Energy of urine from Grape-Nuts alone,† -	—	—	—	—	—	—	104
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	93.60	85.14	96.02	94.30	55.28	90.54
	Of Grape-Nuts alone, -	—	89.52	67.87	—	91.85	—	85.79
	Experiment No. 560, with E. O. (Duration 4 days.)							
	Food eaten:	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
3671	Grape-Nuts, - -	800.0	730.88	93.04	6.16	631.68	17.36	3249
3672	Milk, - - - -	3919.8	521.73	129.75	184.62	207.36	25.48	3132
3673	Cream, - - -	2470.0	679.01	69.41	533.03	76.57	13.34	5533
	Sugar, - - - -	219.6	219.60	—	—	219.60	—	870
	Total, - - -	7409.4	2151.22	292.20	723.81	1135.21	56.18	12784
3676	Feces, from total food, -	150.9	119.42	31.31	24.17	63.94	23.77	824
	Feces,* from food other than Grape-Nuts, -	—	—	5.97	35.88	10.07	—	509
	Feces,* from Grape-Nuts alone, - - - -	—	—	25.34	—	53.87	—	315
	Amount digested from total food, - - - -	7258.5	2031.80	260.89	699.64	1071.27	32.41	11960
	Amount* digested from Grape-Nuts alone, -	—	—	67.70	—	577.81	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	326
	Energy of urine from Grape-Nuts alone,† -	—	—	—	—	—	—	85
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	94.45	89.28	96.66	94.37	57.69	91.00
	Of Grape-Nuts alone, -	—	90.76	72.76	—	91.47	—	87.69

* Estimated by the method described on page 191.

† Computed by assuming that the amount of the energy lost in the organic matter of the urine was 1.25 calories per gram of digestible protein. See explanation page 190.

other times had eaten as large amounts without the least discomfort. Furthermore, in these experiments the quantity eaten was not fixed, but varied with the desires of the subjects at the different meals. Possibly the unpleasant conditions might not have occurred if smaller quantities of the cereal had been eaten. It will be observed, however, that the total quantity of protein per day in the diet was only about 80–86 grams, even including considerable amounts of milk and cream. Indeed, the relatively large quantities of milk consumed were mainly for the purpose of increasing the quantity of protein in the diet, since it was impossible for any of the subjects to eat enough of the cereal to accomplish this. It may be remarked that A. B. A., who was most affected by the diet and had to give up the experiment on the third day, ate less of the cereal than either of the others.

EXPERIMENTS WITH MALTA VITA.

Experiments with this cereal began with breakfast July 2, 1903, with four subjects, two of whom were in the preceding experiments with Grape-Nuts. With three of the subjects the experiments continued four days with twelve meals, and one of these, H. C. S., had been on the same diet two days before the experiment began. The fourth subject continued on the diet three days with eight meals, but since he wished to be absent at the time of supper on the third day, he ate for dinner sufficient to make the total diet for the day equivalent to that for the preceding days. H. C. S. and E. O. each ate 100 grams of the cereal at each meal, as did also R. D. M., except at the first meal, which was 105 grams; the quantities eaten by J. A. R. were not uniform, varying from 90 to 125 grams at the different meals, and 200 grams with dinner on the third day. The quantity of milk in the diet of R. D. M. was exactly the same, to within .2 gram, and that of cream to .8 gram, from meal to meal, throughout the experiment. In addition to his regular diet, H. C. S. had one cup (about one-half pint) of coffee decoction each day, but as this contains no appreciable quantity of nutrients, it is not taken into account.

TABLE 85.

Results of digestion experiments with "Malta Vita." Nos. 561, 562, 563, 564.

Kinds of food:—Malta Vita, milk, cream and sugar.

Subjects:—H. C. S., R. D. M., J. A. R., E. O.

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 561, with H. C. S. (Duration 4 days.)	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
	Food eaten:							
3677	Malta Vita, - - -	1200	1029.00	146.40	18.24	864.36	35.16	4609
3678	Milk, - - - -	7580	996.77	241.80	363.08	391.89	47.00	6125
3679	Cream, - - -	580	153.24	14.85	118.61	19.78	3.07	1402
	Sugar, - - - -	45	45.00	—	—	45.00	—	178
	Total, - - -	9405	2224.01	403.05	499.93	1321.03	85.23	12314
3680	Feces from total food, -	234.2	177.05	49.32	24.94	102.79	41.69	1088
	Feces* from food other than Malta Vita, -	—	—	7.70	24.08	9.13	—	356
	Feces* from Malta Vita alone, - - - -	—	—	41.62	—	93.66	—	732
	Amount digested from total food, - - - -	9170.8	2046.96	353.73	474.99	1218.24	43.54	11226
	Amount* digested from Malta Vita alone, -	—	—	104.78	—	770.70	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	442
	Energy of urine from Malta Vita alone,† - -	—	—	—	—	—	—	131
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	92.04	87.76	95.01	92.22	51.09	87.58
	Of Malta Vita alone, -	—	86.77	71.57	—	89.16	—	81.28
	Experiment No. 562, with R. D. M. (Duration 4 days.)							
	Food eaten:	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
3677	Malta Vita, - - -	1205.0	1033.29	147.01	18.32	867.96	35.31	4628
3678	Milk, - - - -	3753.6	493.60	119.74	179.80	194.06	23.27	3033
3679	Cream, - - -	2495.3	659.26	63.88	510.29	85.09	13.23	6034
	Sugar, - - - -	348.5	348.50	—	—	348.50	—	1380
	Total, - - -	7802.4	2534.65	330.63	708.41	1495.61	71.81	15075

TABLE 85.—*Continued.*

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 562, Con.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
3681	Feces from total food, -	200.4	157.20	44.09	28.88	84.23	28.74	967
	Feces* from food other than Malta Vita, - -	—	—	5.51	34.00	12.55	—	448
	Feces* from Malta Vita alone, - - - -	—	—	38.58	—	71.68	—	519
	Amount digested from total food, - - - -	7602.0	2377.45	286.54	679.53	1411.38	43.07	14108
	Amount* digested from Malta Vita alone, -	—	—	108.43	—	796.28	—	—
	Energy of urine from total food.† - - - -	—	—	—	—	—	—	358
	Energy of urine from Malta Vita alone,† - -	—	—	—	—	—	—	136
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	93.80	86.66	95.92	94.37	59.98	91.21
	Of Malta Vita alone, -	—	89.82	73.76	—	91.74	—	85.85
	Experiment No. 563, with J. A. R. (Duration 3 days.)							
	Food eaten,	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
3677	Malta Vita, - - - -	923.0	791.48	112.61	14.03	664.84	27.04	3545
3678	Milk, - - - - -	3214.8	422.75	102.55	153.99	166.21	19.93	2598
3679	Cream, - - - -	1469.2	388.16	37.61	300.45	50.10	7.79	3553
	Sugar, - - - - -	226.5	226.50	—	—	226.50	—	897
	Total, - - -	5833.5	1828.89	252.77	468.47	1107.65	54.76	10593
3682	Feces from total food, -	167.2	132.93	36.78	20.06	76.09	23.68	807
	Feces* from food other than Malta Vita, - -	—	—	4.20	22.72	8.86	—	313
	Feces* from Malta Vita alone, - - - -	—	—	32.58	—	67.23	—	494
	Amount digested from total food, - - - -	5666.3	1695.96	215.99	448.41	1031.56	31.08	9786
	Amount* digested from Malta Vita alone, -	—	—	80.03	—	597.61	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	270
	Energy of urine from Malta Vita alone,† - -	—	—	—	—	—	—	100
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	92.73	85.45	95.72	93.13	56.76	89.83
	Of Malta Vita alone, -	—	87.73	71.07	—	89.89	—	83.24

TABLE 85.—*Continued.*

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 564, with E. O. (Duration 4 days.)	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
	Food eaten:							
3677	Malta Vita, - - - -	1200.0	1029.00	146.40	18.24	864.36	35.16	4609
3678	Milk, - - - - -	5470.1	719.32	174.50	262.02	282.80	33.91	4420
3679	Cream, - - -	3017.1	797.12	77.24	617.00	102.88	15.99	7295
	Sugar, - - - -	191.6	191.60	—	—	191.60	—	759
	Total, - - -	9878.8	2737.04	398.14	897.26	1441.64	85.06	17083
3683	Feces from total food, -	247.2	193.04	48.53	39.75	104.76	37.87	1187
	Feces* from food other than Malta Vita, - -	—	—	7.55	43.95	11.55	—	552
	Feces* from Malta Vita alone, - - - -	—	—	40.98	—	93.21	—	635
	Amount digested from total food, - - - -	9631.6	2544.00	349.61	857.51	1336.88	47.19	15896
	Amount* digested from Malta Vita alone, -	—	—	105.42	—	771.15	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	437
	Energy of urine from Malta Vita alone.† - -	—	—	—	—	—	—	132
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	92.95	87.81	95.57	92.73	55.48	90.49
	Of Malta Vita alone, -	—	87.37	72.01	—	89.22	—	83.36

*Estimated by the method described on page 191.

†Computed by assuming that the amount of the energy lost in the organic matter of the urine was 1.25 calories per gram of digestible protein. See explanation page 190.

As was the case with the experiments with Grape-Nuts, some of the conditions resulting from the diet in these experiments were unpleasant. There was fermentation, and apparent irritation of the intestine, with accompanying pain for two of the subjects, which, though not so severe as in the case of one subject on Grape-Nuts, necessitated the termination of the experiment with J. A. R. a day before those with the others ended. At the beginning of the experiment this subject thought the diet very palatable and he was very confident that he could continue on it as long as desired. It is possible

that with this subject the conditions which made it necessary to end the experiment may have been due in part to the extra amount eaten for dinner on the third day.

EXPERIMENTS WITH FORCE.

The experiments with Force were made with H. C. S. and E. O., and followed those with Malta Vita without interruption, beginning with breakfast July 6, 1903, and continuing three days with twelve meals. H. C. S. had therefore already been six days, and E. O. four days, on a very similar though not identical diet. H. C. S. ate 100 grams of the cereal for each meal, as he did in the preceding experiments; but E. O. reduced the quantity to 200 grams per day, or two-thirds as much as in the experiments with Malta Vita. He ate 60 grams for breakfast, and 70 grams each for dinner and supper, each day.

The data of the experiment are tabulated on pages 203 and 204.

The other subject of the Malta Vita experiments expected also to continue with the Force, but the intestinal disturbance continued, and became so severe after the first meal of this series, that he was compelled to drop out. Neither H. C. S. nor E. O. suffered any discomfort from the diet, but both had so little relish for it that they were glad to finish the experiments with the last meal of the third day.

TABLE 86.—*Results of digestion experiments with "Force." Nos. 565 and 566.*

Kinds of food:—Force, milk, cream, and sugar.
Subjects:—H. C. S. and E. O.

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 565, with H. C. S. (Duration 3 days.)	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
	Food eaten:							
3684	Force, - - - -	900.0	776.52	88.74	14.85	672.93	25.74	3440
3685	Milk, - - - -	5960.0	765.27	186.55	256.28	322.44	36.36	4542
3686	Cream, - - -	160.0	42.88	3.81	33.60	5.47	.75	363
	Sugar, - - - -	28.5	28.50	—	—	28.50	—	113
	Total, - - -	7048.5	1613.17	279.10	304.73	1029.34	62.85	8458
3687	Feces from total food, -	162.5	121.68	31.49	12.29	77.90	30.40	735
	Feces* from food other than Force, - - -	—	—	5.71	14.49	7.13	—	236
	Feces* from Force alone,	—	—	25.78	—	70.77	—	499
	Amount digested from total food, - - - - -	6886.0	1491.49	247.61	292.44	951.44	32.45	7723
	Amount* digested from Force alone, - -	—	—	62.96	—	602.16	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	310
	Energy of urine from Force alone,† - - -	—	—	—	—	—	—	79
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	92.46	88.72	95.97	92.43	51.63	87.64
	Of Force alone, - -	—	87.85	70.95	—	89.49	—	83.19
	Experiment No. 566, with E. O. (Duration 3 days.)							
	Food eaten:	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
3684	Force, - - - -	600.0	517.68	59.16	9.90	448.62	17.16	2293
3685	Milk, - - - -	4000.0	513.60	125.20	172.00	216.40	24.40	3048
3686	Cream, - - -	500.0	134.00	11.90	105.00	17.10	2.35	1135
	Sugar, - - - -	122.0	122.00	—	—	122.00	—	483
	Total, - - -	5222.0	1287.28	196.26	286.90	804.12	43.91	6959
3688	Feces from total food, -	133.3	104.54	22.66	44.86	37.02	21.91	751
	Feces* from food other than Force, - - -	—	—	4.11	13.85	7.11	—	195
	Feces* from Force alone,	—	—	18.55	—	29.91	—	556

TABLE 86.—*Continued.*

Lab. No.		Weight of material.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Heats of combustion.
	Experiment No. 566, Con.	Gms.	Gms.	Gms.	Gms.	Gms.	Gms.	Cals.
	Amount digested from total food, - - - -	5088.7	1182.74	173.60	242.04	767.10	22.00	6208
	Amount* digested from Force alone, - -	—	—	40.61	—	418.71	—	—
	Energy of urine from total food,† - - - -	—	—	—	—	—	—	217
	Energy of urine from Force alone,† - - -	—	—	—	—	—	—	51
	Coefficients of availability:	%	%	%	%	%	%	%
	Of total food, - -	—	91.88	88.45	84.36	95.40	50.10	86.10
	Of Force alone, - -	—	84.65	68.64	—	93.33	—	73.53

* Estimated by the method described on page 191.
† Computed by assuming that the amount of the energy lost in the organic matter of the urine was 1.25 calories per gram of digestible protein. See explanation page 190.

SUMMARY AND DISCUSSION OF RESULTS.

The purpose of the experiments was to find what proportions of the different nutrients of the food would be digested and made available to the body, and what proportion of the energy of the food would be utilized by the body. These figures which, as previously explained, are designated as coefficients of availability, are summarized in the following table. The upper portion of the table gives the coefficients for the nutrients and energy of the total diet, including milk, cream, sugar and breakfast cereal, whereas the lower portion gives the coefficients for the cereal part of the diet alone.

Results for total diet.—In the three experiments with Grape-Nuts the coefficients for total organic matter agree very closely for all three subjects, the range being from 93.6 to 94.5 per cent. The coefficients for fat, carbohydrates and energy are likewise in very close agreement, but those for protein vary somewhat, the range being from 85.1 per cent. with one subject to 89.3 per cent. with another. The coefficient for the third subject is almost identical with the average for the three. The agreement in these results is therefore considered quite satisfactory.

TABLE 87.

Summary of coefficients of availability of nutrients and energy.

Experiment No.	SUBJECTS.	Kind of breakfast food.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Ash.	Energy.
	Results for total diet.			%	%	%	%	%
558	A. B. A., - - -	Grape-Nuts,	93.95	87.42	95.85	94.41	47.44	90.69
559	R. D. M., - - -	Grape-Nuts,	93.60	85.14	96.02	94.30	55.28	90.54
560	E. O., - - - -	Grape-Nuts,	94.45	89.28	96.66	94.37	57.69	91.00
	Average 3 experiments,		94.00	87.28	96.18	94.36	53.47	90.74
561	H. C. S., - - -	Malta Vita,	92.04	87.76	95.01	92.22	51.09	87.58
562	R. D. M., - - -	Malta Vita,	93.80	86.66	95.92	94.37	59.98	91.21
563	J. A. R., - - -	Malta Vita,	92.73	85.45	95.72	93.13	56.76	89.83
564	E. O., - - - -	Malta Vita,	92.95	87.81	95.57	92.73	55.48	90.49
	Average 4 experiments,		92.88	86.92	95.56	93.11	55.83	89.78
565	H. C. S., - - -	Force, -	92.46	88.72	95.97	92.43	51.63	87.64
566	E. O., - - - -	Force, -	91.88	88.45	87.46	94.29	50.10	86.10
	Average 2 experiments,		92.17	88.59	91.72	93.36	50.87	86.27
	Results for cereal alone.							
558	A. B. A., - - -	Grape-Nuts,	89.27	69.62	—	91.28	—	85.32
559	R. D. M., - - -	Grape-Nuts,	89.52	67.87	—	91.85	—	85.79
560	E. O., - - - -	Grape-Nuts,	90.76	72.76	—	91.47	—	87.69
	Average 3 experiments,		89.85	70.08	—	91.53	—	86.27
561	H. C. S., - - -	Malta Vita,	86.77	71.57	—	89.16	—	81.28
562	R. D. M., - - -	Malta Vita,	89.82	73.76	—	91.74	—	85.85
563	J. A. R., - - -	Malta Vita,	87.73	71.07	—	89.89	—	83.24
564	E. O., - - - -	Malta Vita,	87.37	72.01	—	89.22	—	83.36
	Average 4 experiments,		87.92	72.10	—	90.00	—	83.43
565	H. C. S., - - -	Force, -	87.85	70.95	—	89.49	—	83.19
566	E. O., - - - -	Force, -	84.65	68.64	—	91.36	—	74.18
	Average 2 experiments,		86.25	69.80	—	90.43	—	78.69

In the results of the four experiments with Malta Vita the widest range is in the coefficients of availability of energy, from 87.6 to 91.2 per cent. For the different nutrients and for total organic matter, the agreement in results obtained with the different subjects is very close.

In the two experiments with Force the agreement in results is likewise close, except in the case of the fat, the coefficients for which vary from 87.5 per cent. with one subject to 96 per cent. with the other. Closer agreement than this is hoped for in experiments of this kind. The reason for the large percentage of ether extract in the feces of E. O. during this experiment is not clear. The total quantity of fat in the diet was very much less than in his preceding experiments.

In comparing the averages of the results of the experiments with the different breakfast cereals, it is noticeable that the variations are no larger than those between individual experiments with the same cereal.

In the following table the averages of the experiments with breakfast foods are compared with corresponding results obtained in similar experiments with cereal food materials other than breakfast foods. The coefficients for the different kinds of bread are in every case averages of results of a considerable number of experiments. In a large number of these the diet consisted simply of bread and milk; in the others sugar was also included, and in some cases butter was used, which would correspond to the cream in the experiments with cereal. In all of the experiments with bread, however, the quantity of cereal food formed a much larger proportion of the total diet than in any of those with breakfast foods.

TABLE 88.

Availability of nutrients and energy of total diet.

CEREAL PART OF DIET.	Total organic matter.	Protein.	Fat.	Carbohydrates.	Energy.
	%	%	%	%	%
Grape-Nuts,	94.0	87.3	96.2	94.4	90.7
Malta Vita,	92.9	86.9	95.6	93.1	89.8
Force,	92.2	88.6	90.7	93.9	86.8
Graham bread,	92.2	89.8	94.5	92.3	87.6
Entire-wheat bread,	94.8	92.0	95.8	95.4	89.8
White bread,	97.0	94.2	96.3	97.9	91.6

The total ration in the experiments with breakfast foods contained much larger proportions of milk and cream, and much smaller proportions of cereal material, than that in the experiments with the different kinds of bread. In that case, if the availability of the nutrients were the same in the cereal breakfast foods as in the bread, the coefficients for the total diet containing the breakfast cereals should be larger than those for the diet containing the bread, because the nutrients of the milk and cream are more available than those of cereal food products. It will be seen from a comparison of the data in the table above that the coefficients for protein in the diet containing the breakfast foods are a little smaller than the lowest for the diets containing the bread. The differences in respect to the other nutrients and energy are for the most part less noticeable, but still on the whole in favor of the breads. The inference is, therefore, that the nutrients of the cereal breakfast foods were less available than those of the breads. That this was actually the case is brought out in the following consideration of the estimated coefficients of the cereal portion of the diet alone.

Results for the cereal part of the diet.—The more important feature of these experiments is in the results of the computations of the availability of the nutrients and energy of the cereal part of the diet. These estimates were made, as previously described in detail, by assuming that the availability of the articles of the diet aside from the cereals, that is, the milk, cream and sugar, would be the same as has been found in other experiments with such materials. It has already been explained that the computations cannot be made for fat because the quantity of fat in the cereal foods was so small. The coefficients of availability as thus computed for the cereal alone are given in the lower portion of Table 87.

In the experiments with Grape-Nuts, the coefficients for carbohydrates are practically the same for the three subjects. There is a very small variation in the figures for energy. The variation in the result for protein is a little larger, the range being from 67.9 per cent. with one subject to 72.8 per cent. with another; the result with the third subject is practically a mean between these two. As was explained in regard to the total diet, these agreements are very satisfactory.

Similar agreements are observed in the results with the different subjects in the experiments with Malta Vita. The range in protein was from 71.1 to 73.8 per cent., in carbohydrates from 89.2 to 91.7 per cent., and in energy from 81.3 to 85.9 per cent.

In the two experiments with Force, the agreement of results as regards availability of protein and carbohydrates was reasonably close. The variation in results for energy was rather wider than is desirable.

A comparison of the coefficients of availability of nutrients and energy in the breakfast food alone and in bread alone is given in the table following. The figures for bread alone here given are averages from the results of the same experiments as those for total diet given in the preceding table.

TABLE 89.

Availability of nutrients and energy of cereal food materials alone.

CEREAL FOOD.	Protein.	Carbohydrates.	Energy.
	%	%	%
Grape-Nuts,	70.1	91.5	86.3
Malta Vita,	72.1	90.0	83.4
Force,	69.8	88.5	78.7
Graham bread,	76.0	90.4	82.9
Entire-wheat bread,	82.3	94.1	87.1
White bread,	88.1	97.9	92.0

As regards the availability of the carbohydrates and energy, the results obtained for the breakfast foods compare favorably with those for the graham bread. As regards the protein, however, they do not agree so closely, though the agreement would be closer if the correction mentioned on page 191 were made.

In the case of the breads, the lower availability of the graham flour is ascribed to the presence of the bran, which resists the action of the digestive juices in the alimentary canal. Graham flour is practically wheat meal, and like many of the breakfast foods, is said to contain the whole of the wheat kernel, including

the outer coat, or bran. Finely ground bran appears to be somewhat more available than the coarser material, but the finest of it is less available than white flour. The lower availability of the protein of the breakfast cereals as compared with that of the graham bread may doubtless be due to the coarser condition of the former.

It is possible, of course, that the coefficients of availability of the nutrients of the food other than cereal should be smaller for the subjects of these experiments than those assumed for the purpose of estimating the availability of the cereals. In that case, the coefficients for the nutrients of the cereals would be larger than those given in the table above. It is believed, however, that the factors referred to were reasonably correct for these subjects, and that the results as computed for the cereals are not far from the truth; but even if the factors were incorrect, the computed coefficients for the different cereals would still be comparable with each other, because the same factors were used in each case. The same factors were also used in computing the results of the experiments with breads, so that the comparison given in the table above is warranted, and the deductions drawn from the data there are valid.

CONCLUSION.

In these experiments, the availability of the different brands of breakfast foods, all said to consist largely of wheat, was found to be smaller, especially in the case of the protein, than that of the nutrients of wheat flour. Two of the three different brands used in the experiments, though made at different factories, were quite similar in character, but the third was somewhat different from either. The uniformity of the results is therefore the more interesting.

The total number of experiments, and the number of different brands included, is too small to warrant final conclusions from the results with respect to the availability of wheat breakfast foods in general. It is interesting to note, however, that the results here reported are in very close accord with those of other experiments with the same and different kinds of wheat breakfast foods made elsewhere but still awaiting publication.

THE NUTRITIVE VALUE OF PREPARED CEREAL PRODUCTS.

BY R. D. MILNER.

Within recent years there has come into very popular use in this country a class of cereal food products known as "breakfast foods," or "breakfast cereals." These products are in general attractive and palatable, and afford a pleasing variety in the diet; and because of special treatment in manufacture, which in many cases includes partial or entire cooking, their preparation for the table is very materially simplified. In view of these conditions it is easy to understand why this class of food materials should increase in popular favor.

In spite of the intrinsic value of the materials, however, it is doubtless true that their prevalent use is due in very large measure to the method of advertising them. No class of food materials is so extensively or ingeniously advertised. According to the statements made for them, they are not only the most perfect of foods, sufficient in themselves for all man's needs for nutriment, but they also have a variety of other virtues, from that of brain tonics to that of substitutes for pie crust. Some of the claims made for them are founded on fact, others are obviously preposterous, and many contain an ingenious mixture of fact and fancy.

Whether this class of food materials will be permanently as popular as at present it is impossible to say. It is noticeable that many of the brands remain on the market only a short time; but new ones appear at frequent intervals, until their name is legion. In some cases the disappearance is due to failure to catch popular fancy, but in many cases there is simply a change in name, in order to attract attention to something seemingly new, but in reality an old article under a new name.

This much is quite certain, however; cereal food products are very desirable articles of diet, and the prepared cereal products now meet a very widespread demand. If they were sold more cheaply, and people understood more about them, very probably there would be a considerable permanent demand for them. In view of the fact that there is such a wide difference in the cost of different brands, a summary of our present knowledge concerning the actual nutritive value and relative economy of this class of food materials would seem especially desirable. Inasmuch as a number of experiment stations, among them this one, have been making special studies of these products, considerable knowledge concerning them is now available. It is the purpose of the present article to summarize the information that has been thus far obtained.

ORIGIN OF THE BREAKFAST FOOD.

The use of "porridge" made by simply boiling coarsely ground wheat or oats has long been general. The adoption of such materials very naturally followed the immigration of the English, Irish and Scotch races to this country, and the taste for porridge has persisted and developed here.

The coarsely ground wheat and oat meals required prolonged boiling to render them palatable and more capable of digestion. An important improvement in this respect was introduced in the manufacture of rolled oats. By this process the grain is first softened by steaming, then crushed between rollers and dried. The result of such treatment is that the material is already partially cooked, and the cell walls of the grain are ruptured by the crushing, so that the product can be prepared for the table in much less time than the untreated oatmeal. Similar treatment was eventually applied to wheat, corn, and rice, and other methods of treatment were also devised, resulting in the production of a considerable variety of dietary articles that were found to be palatable and easily prepared for the table.

In earlier times "porridge" more commonly comprised the whole or a large part of at least one meal of the day, usually breakfast. In more recent years the prepared cereal products that have largely supplanted the coarser boiled meals have taken a less important place in the diet, and are now used chiefly as one of several dishes in a meal, instead of forming the bulk of

it. They are still eaten oftener with breakfast than with any other meal, however, hence it has come about that the whole class of especially prepared cereal foods now on the market is commonly designated as "breakfast foods."

METHODS OF PREPARATION.

The exact details of the methods of preparing different brands cannot be given, because many manufacturers refuse to let their processes be known. Indeed many of them claim to possess secret processes of manufacture by which the nutritive value of their product is marvelously enhanced. No thoughtful person need be deceived by any such claim. It is perfectly obvious that the nutritive value of any prepared cereal product depends entirely upon that of the grain from which it is prepared. The only special virtue that may be claimed for any process of preparation is that it may render available to the body a greater proportion of the total nutritive material in the grain than can be obtained from the same grain prepared by some other process.

These supposed secrets of different methods of manufacture are therefore of little importance. The more important features of the different processes are well understood, and a brief mention of these may help to an understanding of the nature of different kinds of prepared cereals.

Cleaning the grain.—The first step consists of the cleaning of the grain. In well appointed factories this includes not only winnowing and washing, but also the removal of dirt, foreign seeds, and other impurities, by means of ingenious forms of apparatus. It is doubtless true of most if not all of these cereal products that the grain is quite thoroughly cleansed before it is further treated.

Partial or complete cooking.—In the simple, old-fashioned breakfast foods, the preparation consisted chiefly in removing the outer coat, or bran, and sometimes in cracking or crushing the grain. Hulled corn was prepared by maceration in a weak solution of lye, whereby the tough skin was removed. The lye also imparted to the corn a peculiar flavor. Barley was sometimes treated in a similar manner. In some cases the corn was also parched to improve its flavor and keeping qualities, and barley was "pearled."

Several of the breakfast foods on the market at the present day are prepared in a very simple manner, by removing the outer coat or bran and then crushing or rolling the rest of the grain. These products require considerable cooking before they are eaten. With other brands the treatment is carried much further. Some of them are partially cooked, and while still requiring some cooking, the time of cooking is much less than for materials not so treated. Some brands are said to be wholly cooked, and ready to be eaten as they are taken from the package. Some brands are claimed to be not only cooked, but also predigested. Further than this it is hardly possible to go.

In the case of the partially cooked products, the cooking may be done by steam, the grains being softened in this way and then passed between rollers and dried, as already explained in the case of rolled oats. The cooking may be carried still further, and the grains rolled more thinly, producing the so-called "flaked" cereals. Or the raw grains may be first flaked and then cooked by parching or toasting. Sometimes the raw grain is moistened with water or other liquid, then cooked by roasting or parching, and finally crushed. Those products which look like dried crumbs may be prepared in this manner. In preparing the so-called "shredded" products the softened grain is worked by machinery into shreds that are deposited in layers, which are then more or less closely pressed together and further cooked by parching or toasting. The majority of these toasted or parched preparations, either shredded or flaked, are cooked to such extent that they may be eaten without further cooking.

Treatment with malt.—In the preparation of "predigested" or "malted" cereal foods there is another step in the process, which has for its object the conversion of starch into sugar. The significance of such treatment will perhaps be plainer when some facts regarding the process of natural digestion of starch are first considered. The purpose of digestion is to convert food substances into materials that may be absorbed from the alimentary canal and taken into the blood. The digestion of starch, which of itself is not soluble, is accomplished by the action of ferments present in the digestive juices produced in the body. One such ferment is present in the saliva, and a

much more active one is present in the pancreatic juice, and by means of this the starch of food is converted into a kind of sugar known as maltose (malt sugar), which is soluble. Before being passed into the blood, however, the maltose is still further changed into another kind of sugar known as dextrose, or glucose.

Whatever starch is not thus converted into sugar by digestion is lost as food. While raw starch is not readily digested by man, cooked starch is in general quite easily disposed of by persons in normal health. On the other hand, persons with weak digestive powers sometimes find it difficult to digest starch even though it is properly cooked. Any process, therefore, which accomplishes the necessary conversion of starch to sugar just explained, to that extent relieves the digestive organs; and so much of the starch as is thus converted may be said to be at least partially "predigested."

The starch of grain may be to a certain extent converted into sugar artifically. When seeds of grain begin to sprout the starch present is transformed into sugar by the action of a ferment, known as diastase, which nature apparently provides for the benefit of the sprouting germ. This ferment is able to change into maltose a much larger quantity of starch than that of the grain in which it is formed. When barley is sprouted and the growth arrested before the sprout has reached any considerable length, a product known as malt is formed. This malt may be ground and mixed with a large amount of other grain, and if the mass is moistened and kept at a warm temperature the ferment in the malt will act upon the starch of the added grain and convert some of it into malt sugar. In this way the so-called predigested or malted foods may be produced. The extent to which the starch of cereals is actually converted to sugar by such process is considered later.

It should be especially noted here, however, that the kind of sugar thus produced is chiefly malt sugar (or maltose) and not grape sugar (or glucose), though the latter might be present in small quantity if the fermentation were continued long enough. But long continued fermentation would be likely to produce undesirable flavors. It is quite likely that where grape sugar is present in considerable quantity it has been added in commercial form rather than produced by the action of ferments.

Before leaving the topic of preparation a word may be said regarding the care with which the prepared cereal products are handled. Throughout the process strict attention is paid in most instances to cleanliness, and the neat, well closed packages in which the goods are marketed generally keep them in excellent condition until they reach the consumer. This is a very decided improvement on the old-fashioned cereals in bulk, scooped out of very questionable bins and barrels. This is not true in all cases, however, as was noticed in connection with one of the investigations considered in preparing this article. To quote the investigators, "All the samples collected for analysis were guaranteed fresh goods by the dealer from whom they were purchased. In spite of this precaution a number of packages when opened were found not only musty but infested with moths or the larvæ of beetles. All such samples were rejected as not fairly representing the goods. Some method should be devised whereby such stale goods should be withdrawn from the market, or replaced by fresh preparations. The interests of both the manufacturers and dealers would seem to demand that the consumer should have a reasonable assurance as to the quality of the goods purchased."

NUTRITIVE VALUE OF CEREAL PREPARATIONS.

Several factors must be considered in estimating the nutritive value of any food material. The two that are of especial importance are the composition of the material and its digestibility; that is, it must contain some of the different nutrients —protein, fat, carbohydrates and mineral matters—and it must be capable of digestion, so that the nutrients may be absorbed from the material as it passes through the alimentary canal. In addition to these the food should be palatable in itself or capable of being made palatable by cooking or other mode of preparation, and it should also "agree" with those who eat it; that is, it should cause no unpleasant feelings or disturbance of bodily functions when eaten. The relative cost of the nutrients in the given food material should also be taken into account in a comprehensive discussion of nutritive value.

Little comment is necessary regarding the palatability of prepared cereals. The extensive use of these products is sufficient indication that they are relished, because if they were

not no amount of advertising could make them as popular as they are. Preferences for different brands are of course matters of individual taste, which does not enter into this discussion.

The question as to what foods ''agree'' with different persons depends so largely upon individual peculiarity that not much can be definitely stated concerning it. Unfortunately, cases in which foods that are quite universally considered wholesome appear to be injurious to some individuals are numerous. Just why people differ in this respect it is not easy to determine, and it is practically impossible to state any general principle in the matter. Every one must learn for himself what foods ''agree'' with him and what ones do not. The extensive use of the prepared cereals may be taken also as an indication that they agree quite generally with those who eat them.

COMPOSITION OF CEREAL FOODS.

Any substance is valuable as food so far as it furnishes the body with material to be used for growth and repair of waste of tissues, and for supplying energy for bodily warmth and for muscular work. The ingredients of food thus utilized by the body are commonly called protein, fat, carbohydrates and mineral salts. In addition the body requires the oxygen of the air, and water, which though physiologically necessary are not ordinarily designated as nutrients. Just how the different nutrients are used in the body in all cases may be somewhat undecided, but it seems undoubtedly true that for building up and repairing muscular tissues, protein is essential. The fats and carbohydrates, together with protein not otherwise utilized, are oxidized to yield energy for bodily warmth and muscular activity, though if the quantities of nutrients are larger than are immediately needed, the surplus may be stored in some form (chiefly fat) for future use. The mineral matters are useful for forming bone and other parts of the body, and in other ways, but the functions of the salts are much less definitely understood than those of the other ingredients of food.

Some or all of the nutrients mentioned are present in all foods, though in varying forms and proportions in different materials. The kinds and amounts that are present in any food

are learned by chemical analysis. During the past few years a very large number of analyses of cereal breakfast foods have been made, including a great variety of different brands, so that there is now available a large amount of definite information regarding the composition of this class of food products.

Although all of this information has been considered in the preparation of the present discussion, a complete compilation of analyses is not given because it is too large for the present purpose. In place of this a sort of summary is presented in Table 90 below, which is sufficient to afford an intelligent idea of the composition of this class of food products. Although the number of different brands included in the table is small in comparison with the total number on the market, a sufficient variety is given to allow a fair comparison of similar products from different sources. The brands here included were taken almost entirely at random, the only care in selection being given to include a fair proportion of preparations that are more or less common in this region.

The different kinds of cereal preparations are grouped in the table according to the grain from which they are made. The greatest variety is found in the wheat products. These are arranged in the table in two divisions, one including those products that are either uncooked or only partially cooked when purchased, and require more or less cooking to prepare them for the table, and the other including brands that when purchased are sufficiently cooked to be eaten as taken from the package. The former division is much the larger, because the preparations of this character are the more numerous. The straight wheat preparations that are ready to eat are not so numerous as those composed of wheat and barley malt. The malted products are given in a group by themselves.

The group of corn products likewise comprises two divisions, corresponding to those of wheat. The corn preparations that require some cooking are also more numerous than those that are ready to eat. For purposes of comparison, the composition of boiled hominy as commonly eaten is given in the table.

The oat products comprise old fashioned oatmeal, that was entirely uncooked, and rolled oats, which are partially cooked by steam in the process of preparation. The composition of boiled rolled oats is given also.

TABLE 90.—*Composition of prepared cereal products and some miscellaneous foods.*

FOOD PRODUCT.	No. of analyses.	Water.	Protein.	Fat.	Crude fiber.	Carbohydrates.†	Ash.	Energy per gram.
WHEAT PREPARATIONS.		%	%	%	%	%	%	Cals.
Uncooked and partially cooked:								
Cream of Wheat, - -	7	9.6	12.5	1.0	(.5)	76.5	.4	4.031
Hecker's Farina, - -	2	11.4	10.7	.9	(.5)	76.6	.4	3.922
Pettijohn's Breakfast Food, -	7	10.1	10.9	2.0	(1.9)	75.4	1.6	3.985
Pillsbury's Vitos, - -	3	9.7	12.7	1.4	(.6)	75.5	.7	4.038
Ralston's Health Food, -	6	10.6	13.2	1.5	(1.2)	73.7	1.0	4.001
Rolled Wheat:								
Brand unknown, - -	1	11.7	9.5	1.3	(1.5)	76.0	1.5	3.864
Fruen's, - - - -	1	10.6	9.5	2.0	(1.8)	76.2	1.7	3.937
Old Grist Mill, - -	2	10.0	10.8	2.0	(2.0)	75.8	1.4	3.996
Average, - - -	4	10.6	10.2	1.8	(1.8)	75.9	1.5	3.947
Wheat Flakes:								
Crescent, - - -	1	9.5	9.3	1.7	(1.6)	76.3	3.2	3.902
Fruen's, - - - -	1	9.7	9.6	1.9	(1.8)	77.2	1.6	3.976
Golden Sheaf, - - -	1	9.4	9.7	1.4	(2.2)	77.8	1.7	3.960
Granose, - - -	5	9.0	13.4	1.1	(1.8)	73.7	2.8	3.975
Sioux, - - - -	1	8.9	10.8	1.5	(1.6)	77.2	1.6	4.008
White's, - - - -	1	11.3	15.6	1.9	(2.7)	69.4	1.8	3.996
Average, - - -	10	9.4	12.2	1.4	(1.9)	74.6	2.4	3.971
Wheatena, - - - -	8	8.0	14.2	3.1	(1.0)	73.3	1.4	4.191
Wheatlet, - - - -	9	10.7	12.6	1.9	(1.1)	73.7	1.1	4.003
Wheatine, - - - -	2	10.2	10.5	1.9	(1.3)	75.7	1.7	3.965
Average of uncooked and partially cooked, - -	58	9.8	12.3	1.8	(1.3)	74.8	1.3	4.022
Cooked:								
Parched Farinose, - -	6	8.1	14.3	3.0	(1.1)	73.2	1.4	4.183
Shredded Whole Wheat, -	14	8.1	10.6	1.4	(2.1)	78.1	1.8	4.025
Average of cooked, - -	20	8.1	11.7	1.9	(1.6)	76.7	1.6	4.077
Average of all, - -	78	9.4	12.1	1.8	(1.4)	75.3	1.4	4.032
OAT PREPARATIONS.								
Oatmeal, old-fashioned, -	16	7.3	16.1	7.2	(.9)	67.5	1.9	4.438
Rolled oats:								
Buckeye, - - - -	4	8.1	15.3	7.4	(1.2)	67.3	1.9	4.402
Hecker's, - - -	3	8.3	17.1	7.7	(.7)	65.1	1.8	4.442
Hornby's, - - -	6	8.6	15.6	7.4	(1.1)	66.7	1.7	4.394
Quaker, - - - -	10	7.9	16.3	7.5	(1.5)	66.6	1.7	4.440
Ralston's, - - -	2	7.3	17.0	6.9	(2.2)	66.9	1.9	4.438
Saxon, - - - -	1	9.7	17.4	7.1	(1.0)	63.5	2.3	4.337
Average, - - -	26	8.2	16.1	7.4	(1.3)	66.5	1.8	4.415
Average, oatm'l, rol'd oats,	42	7.8	16.1	7.3	(1.1)	66.9	1.9	4.423
*Oatmeal, boiled, - -	7	84.5	2.5	.7	—	11.6	.7	.697

* Analyses of samples of such materials as actually prepared in different households.
† The figures for carbohydrates include those for fiber.

TABLE 90.—*(Continued.)*

FOOD PRODUCT.	No. of analyses.	Water.	Protein.	Fat.	Crude fiber.	Carbohydrates.†	Ash.	Energy per gram.
CORN PREPARATIONS.		%	%	%	%	%	%	Cals.
Uncooked and partially cooked:								
Cerealine Flakes,	2	10.3	8.9	.8	(.5)	78.6	1.4	3.892
Hominy:								
Hecker's,	8	11.0	8.6	.7	(.4)	79.4	.3	3.899
H. O. Co.'s,	2	11.2	8.4	.7	(.3)	79.4	.3	3.887
Nichol's,	1	9.3	8.5	.4	(.3)	81.6	.2	3.957
Average,	11	10.9	8.6	.6	(.4)	79.6	.3	3.898
Samp:								
Baltic Mills,	1	11.4	8.3	.8	(1.0)	79.2	.3	3.882
Nichol's Snow White,	1	10.3	8.2	.3	(.4)	80.9	.3	3.901
Average,	2	10.8	8.3	.5	(.7)	80.1	.3	3.892
Average of uncooked and partially cooked,	15	10.8	8.6	.6	(.5)	79.5	.5	3.894
Cooked:								
Korn Krisp,	2	6.2	10.6	2.5	(1.6)	78.0	2.7	4.123
Toasted Corn Flakes,	1	9.6	9.2	.5	(.6)	79.0	1.7	3.898
Average,	3	7.3	10.1	1.8	(1.2)	78.4	2.4	4.046
*Hominy, boiled,	3	82.6	1.8	.1	—	14.9	.5	.740
Cornmeal, granular,	19	12.5	9.2	1.9	(1.0)	75.4	1.0	3.877
RICE PREPARATIONS.								
Cook's Flaked Rice,	5	10.2	8.3	.3	(1.2)	80.9	.3	3.907
Ordinary decorticated,	6	11.9	8.0	2.0	—	77.0	1.1	3.884
Polished,	13	12.3	6.9	.3	—	80.0	.5	3.788
*Rice, boiled,	6	82.7	1.7	.4	—	14.9	.3	.762
BARLEY PREPARATIONS.								
Ralston's Barley Food,	2	8.8	10.6	.8	(1.2)	78.9	.9	4.003
Pearled barley,	3	11.5	8.5	1.1	(.3)	77.8	1.1	3.863
MIXED GRAINS.								
Granola (wheat, corn, oats),	3	9.8	12.2	.7	(.9)	76.2	1.1	3.973
Grape-Nuts (wheat, barley),	11	5.6	12.2	1.0	(1.7)	79.3	1.9	4.131
MALTED PREPARATIONS.								
From wheat:								
Brittle Bits,	1	6.9	14.1	.5	(1.0)	77.0	1.5	4.098
Force,	9	9.0	12.1	1.4	(1.8)	74.8	2.7	3.974
Malt Breakfast Food,	3	7.8	13.6	1.7	(.7)	75.7	1.2	4.126
Malta Vita,	3	9.9	11.8	1.4	(1.8)	74.3	2.6	3.935
Average,	16	8.8	12.5	1.4	(1.4)	75.0	2.3	4.005
From oats:								
Malt Oats Breakfast Food,	1	6.4	16.7	5.4	(.9)	69.7	1.8	4.398
Norka Malta Oats,	1	9.3	15.8	4.9	(2.7)	67.0	3.0	4.186
Average,	2	7.9	16.2	5.2	(1.6)	68.3	2.4	4.292

* Analyses of samples of such materials as actually prepared in different households.
† The figures for carbohydrates include those for fiber.

TABLE 90.—*(Continued.)*

FOOD PRODUCT.	No. of analyses.	Water.	Protein.	Fat.	Crude fiber.	Carbohydrates.*	Ash.	Energy per gram.
		%	%	%	%	%	%	Cals.
From mixed grains:								
F. F. V. (wheat and corn),	1	8.6	11.6	1.7	(.7)	77.0	1.1	4.065
Miscellaneous foods:								
Corn bread (johnnycake),	5	38.9	7.9	4.7	—	46.3	2.2	2.840
Wheat bread, white, -	198	35.3	9.2	1.3	(.5)	53.1	1.1	2.885
Crackers, - - - -	71	6.8	10.7	8.8	(.5)	71.9	1.8	4.459
Macaroni, - - - -	11	10.3	13.4	.9	—	74.1	1.3	3.973
Beans, pea, dried, - -	11	12.6	22.5	1.8	(4.4)	59.6	3.5	3.953
Peas, dried, - - -	8	9.5	24.6	1.0	(4.5)	62.0	2.9	4.099
Milk, - - - - -	—	87.0	3.3	4.0	—	5.0	.7	.751
Sugar, - - - - -	—	—	—	—	—	100.0	—	3.950

*The figures for carbohydrates include those for fiber.

Preparations of rice are far less numerous than those of the other grains just referred to. Only one brand of such product is therefore given. The composition of polished rice uncooked, and as commonly cooked by boiling, is shown for comparison.

The composition of one brand of prepared barley is given, and also that of ordinary pearled barley. This grain is not used alone very extensively in this country in the same way as the other cereals. Its chief use as a constituent of prepared cereals is in the form of malt.

The malted breakfast foods contain a considerable proportion of barley. The brands that consist of wheat and barley malt are the more numerous, but some of the other grains are also thus combined. The table shows the composition of malted wheat and oat products.

In most cases the composition given is not simply the result of one analysis, but the average of analyses of several samples of the same brand of goods obtained in different markets.

In order to compare the quantities of nutrients in the cereal preparations with those furnished by other foods, figures showing the composition of several common food materials are also included in the table.

A little consideration of the figures in the table will show that the actual variations in composition between different products from the same grain are in the main comparatively

small. Of course, if such an analysis as the one given for Crescent wheat flakes, with 9.3 per cent. protein and 76.3 per cent. of carbohydrates, were compared with the one for White's wheat flakes, with 15.6 per cent. of protein and 69.4 per cent. of carbohydrates, there might appear to be a decided advantage in favor of the latter because of the higher proportion of protein, this being the more important nutrient. It should be observed, however, that this comparison is between only one analysis of each sample. Although the figures show the relative merits of the two particular lots from which the samples were taken, it would not be fair to draw final conclusions regarding these or any other brands from a comparison of single anaylses. The composition of the same brand of goods from the same factory may differ so much that a comparison of two other samples might show these figures reversed. For instance, in the five analyses of Granose flakes included in the average composition given for this brand, the protein content ranged from 11.5 to 15.6 per cent., and that of carbohydrates from 69.7 to 76.8 per cent. Similar differences were also found in separate analyses of other brands. The first point to be observed, then, is that the same brand from the same factory is hardly more uniform in composition than similar products from different factories.

In considering different brands, therefore, the fairer comparison is that between averages of several analyses of the same product, obtained in different markets or in different seasons. Among the wheat preparations, the average of eight analyses of Wheatena is almost identical with that of six analyses of Parched Farinose; and the average of nine analyses of Wheatlet is practically the same as that of six analyses of Ralston's Health Food. The widest range in average figures in the wheat products here included is between the Shredded Wheat with 10.6 per cent. of protein and 78.0 per cent. of carbohydrates and Parched Farinose with 14.3 per cent. of protein and 73.2 per cent. of carbohydrates. This difference is appreciably smaller than the one noticed above between separate analyses.

Among the corn products, in the eight analyses of Hecker's Hominy, the range of protein was from 6.8 to 9.5 per cent. and that of carbohydrates from 77.3 to 81.4 per cent. This is by no means a wide variation, and the agreement of five of the

analyses with the average of all eight was very close indeed. It is noticeable that the figures for composition of all three brands of hominy are so close as to be considered practically identical; and it is also especially noticeable that the figures for composition of Samp and Cerealine Flakes are likewise practically the same as those for Hominy. In other words, the variations in composition of this sort of product were very small whether the goods were of the same brand and made in the same factory, or different brands made in different factories. This is the more remarkable when it is considered that the data were taken at random from the compilation. The average composition of the two brands of fully cooked corn preparations is slightly but not markedly different from the hominy and samp.

Among the oat preparations, in the six analyses of Quaker Oats averaged together the range in protein was from 14.6 to 17.6 per cent., and in carbohydrates from 63.9 to 68.0 per cent. Hecker's Oats ranged from 14.4 to 18.9 per cent. in protein and from 62.7 to 66.9 per cent. in carbohydrates. The range in average figures was from 15.3 per cent. of protein and 67.3 per cent. of carbohydrates in Buckeye Oats, to 17.1 per cent. of protein and 65.1 per cent. of carbohydrates in Hecker's Oats. The average of twenty-six analyses of several different brands of rolled oats is almost exactly the same as that of eighteen analyses of old fashioned oatmeal.

In the case of the oats, and especially in the case of the corn products, the variations between different analyses of the same brand and average analyses of different brands were in general smaller than in the case of the wheat products. The variations observed in the composition of wheat products, however, are by no means surprising. In fact even wider variations are possible. The chemical composition of wheat is not a fixed characteristic. Different varieties of wheat differ widely in this respect. Samples of ordinary wheat with protein content as low as 7 per cent. have been analyzed, and varieties of macaroni wheat with 19 per cent. are not uncommon. Obviously, then, cereal products made even by the same process from different varieties of wheat would be likely to differ in composition. Furthermore, the composition of the same variety of wheat may vary with changes in climate, soil, etc., so that uniformity could not always be assured even by using always the same variety.

The same is likewise true of other grains. For instance, the composition of different samples of the same variety of corn grown upon the same field during the same season has been found to vary according to differences in the amounts of nitrogenous fertilizer applied on different parts of the field. The uniformity in the composition of the corn products noted above may therefore be regarded as accidental.

Such facts as these show that little reliance can be placed upon the analyses printed upon the packages of some brands, unless the analysis was made of a sample of the goods actually enclosed in the package, which would not always be practicable. Of course it is just as possible that the analysis may be too low as that it may be too high; the only criticism intended here is that the purchaser should not place too much reliance upon the figures printed upon the package, though they may serve as a general indication.

It appears, then, that different prepared cereal products from the same grain show relatively small differences in composition when average figures are considered. It is interesting to compare them also with other common food products from the same grains. Such a comparison is afforded by the figures in the following table:

TABLE 91.

Average composition of various cereal food products.

	Protein.	Fat.	Crude fiber.	*Carbohydrates.	Energy per gram.
	Per ct.	Per ct.	Per ct.	Per ct.	Cals.
Oatmeal,	16.1	7.3	1.1	66.9	4.438
Oat, preparations,	16.1	7.4	1.3	66.5	4.423
Wheat flour (graham),	13.3	2.2	1.9	71.4	3.975
Wheat flour (entire),	13.3	1.9	.9	72.4	3.990
Wheat, preparations,	12.1	1.8	1.4	75.3	4.032
Corn meal, unbolted,	8.4	4.7	1.7	74.0	4.030
Corn meal, bolted,	9.2	1.9	1.0	75.4	3.877
Corn, preparations,	8.6	.6	.5	79.5	3.894
Rice, decorticated,	8.0	2.0	.5	77.0	3.884
Rice, polished,	7.4	.3	.4	79.2	3.788
Rice, preparations,	8.3	.3	.4	80.9	3.907
Barley, pearled,	8.5	1.1	.3	77.8	3.863
Barley, preparations,	10.6	.8	1.2	78.9	4.003

*Includes crude fiber of preceding column.

With the prepared wheat products, some of which are made from the whole of the grain, and some with the outer coating or bran removed, we may compare graham flour, which is also supposed to contain the whole of the kernel, and entire wheat flour, which is said to lack the outer coating of the grain. The composition given for graham flour is the average of thirteen analyses, and that of entire wheat flour the average of nine analyses, of different samples. The figures for prepared wheat products are the average of all seventy-eight analyses of such preparations considered in Table 90. Comparing these average figures it will be seen that the flours contained a trifle more protein and fat and less carbohydrates than the preparations, but the differences are much smaller than were observed between separate analyses of the same preparation. For all practical purposes the average composition of the preparations may be considered to be just the same as that of the flour.

The two common forms of oat food products are oatmeal, which is simply hulled oats ground, and rolled oats, which are partly cooked by steam in preparation. The practical identity of the two in composition has already been mentioned.

The corn preparations agree quite closely in average composition with the commonly used bolted or granular corn meal. The rice preparations agree with ordinary polished rice, and the barley preparations are much the same as pearled barley.

It is plain from such figures that as regards either the kinds or quantities of nutritive ingredients the common sorts of cereal preparations have no advantages over the ordinary food products from the same grains. There are, indeed, a few brands which contain not only the cereals, but such other substances as gluten, or sugar, or salt, added to them to increase the quantity of one or the other ingredients; but these are chiefly special brands prepared for special purposes, and comprise but a small proportion of the total number of prepared cereal products. They are therefore not considered here.

Products from different grains compared.—The foregoing comparison has been between different products from the same grain. If the preparations from the different grains are compared it will be noticed that as sources of protein the oat products rank considerably higher than those of the other grains,

containing a third as much more protein than the wheat products, and nearly twice as much as the corn or rice products. As sources of fat also the oat products outrank the others. In fact the quantity of fat in the preparations from the other grains is in general too small to be of much consideration. In the case of the wheat preparations the lack of fat is due to the fact that most varieties of wheat contain but a small proportion of fat. In the case of the prepared corn products the absence of fat is noticeable, because corn contains usually about 4 to 5 per cent. of fat. In the composition of unbolted corn meal given in Table 91, there is 4.7 per cent. of fat. This is present mostly in the germ, which is usually removed in the production of ordinary bolted corn meal, because of the tendency of the oil to become rancid and spoil the meal. Apparently the germ is largely removed in the manufacture of many of the prepared corn products, though a few analyses of cooked corn preparations have shown from 2 to 3 per cent. of fat present.

Inasmuch as the functions of food are to build tissue and to yield energy, comparison between different foods is sometimes based on their protein content and their energy value. In respect to the quantities of nutrients and energy actually contained, the four most important grains would stand in this order: oats, wheat, corn, and rice, the two latter being about equal. It should be kept in mind, however, that the final judgment as to actual nutritive value is based upon the proportions of protein and energy actually digested and made available to the body. The digestibility of the cereal products is considered later.

Crude fiber.—Everyone is familiar with the tough woody fiber of vegetables. In chemical analyses such material is designated as crude fiber. The outer coat of grains, which is protective, contains a considerable proportion of this material. Crude fiber is almost entirely undigested by man. For this reason, with some of the preparations, attempts are made to remove the extreme outer coat of the grain during the process of manufacture, and for some brands the claim is made that all such material has been removed. The extent to which this is true may be estimated from the figures for crude fiber in Tables 90 and 91. For instance, in shredded wheat preparations

apparently the whole of the wheat kernel, including the outer coat, is used since the quantity of crude fiber, 2.1 per cent. on the average, indicates that none of it has been removed in the preparation of this product. The wheat berry contains, according to an average of nearly 200 analyses, at least 2 per cent. of crude fiber. On the other hand, some of the other preparations contain only 0.5 per cent., which would indicate that the larger part of this material had been removed.

Mineral matters.—The various mineral salts present in food are commonly designated in tables of analyses as ash, because when the sample analyzed is completely burned they remain as ash and are weighed as such. These mineral substances are a very important and necessary ingredient of food, but their use by the body has as yet been much less thoroughly studied than that of the other ingredients, hence not so much is definitely known concerning their functions. Mineral matters are present in the various tissues of the body, and especially in the bones, and they appear to be indispensable to a normal action of the nutrient fluids and digestive juices. A certain supply is therefore necessary, but much less than that of the other ingredients of food. The total amount of ash or mineral matter present in the human body is small as compared with that of other substances, and the quantity in the ordinary diet appears to be abundant. It is quite noticeable, however, that those who know the most about these substances are generally the least ready to make definite and sweeping statements concerning them. The contrast between this and the positiveness with which many persons discourse about them is marked, and has its moral.

So far as the different cereal products are concerned, it will be noticed that a large majority of them contain a small but appreciable amount of mineral matters; but until more is known about the different kinds present and their importance in normal nutrition, it will be obviously impossible to compare the different cereals as sources of mineral matters.

Cereal preparations compared with other foods.—At the end of Table 90 are given the figures representing the composition and energy value of a few common vegetable foods. It is interesting to compare these with the figures for the prepared cereal

products. The corn bread contains a little less protein and energy than the corn preparations, because of the larger proportion of water present; but the uncooked corn preparations when cooked contain much more water than the corn bread, as shown by the composition given for boiled hominy. Wheat bread also contains more water than the wheat preparations, and a little less protein and energy. Crackers with nearly the same water content as the wheat preparations contain a little less protein but considerably more energy, owing to the fat used in making them. Macaroni has much the same composition as the wheat preparations. The dried beans and peas are fully equal in energy value to any of the cereal preparations except those from oats, and contain appreciably more protein.

The advertisements of many of the cereal preparations compare the products with beef in regard to nutritive value, claiming that a pound of the cereal is equal to four to ten pounds of beef. Although such claims are too obviously preposterous to deceive thoughtful persons, an actual comparison of these two classes of food materials is worth consideration. The following figures afford a comparison of both as sources of protein and energy.

	PROTEIN.	ENERGY PER GRAM.
Oat preparations, - - - -	16.1 per cent.	4.423 calories.
Wheat preparations, - - -	12.1 per cent.	4.032 calories.
Corn preparations, - - -	8.6 per cent.	3.894 calories.
Rice preparations, - - -	8.3 per cent.	3.907 calories.
Beef, lean round, - - - -	19.5 per cent.	1.795 calories.
Beef, fat round, - - - -	16.1 per cent.	3.104 calories.
Bread, white, - - - -	9.2 per cent.	2.885 calories.
Bread, graham, - - - -	8.9 per cent.	2.872 calories.
Cheese, full cream, - - -	25.9 per cent.	4.674 calories.
Potatoes, - - - - -	2.2 per cent.	.892 calories.

With regard to the total amount of energy, the cereal products are actually superior to lean beef, though much less superior to fat beef. But even the largest amount of energy from cereals, namely that from oat preparations, is hardly two and a half times greater than that from lean beef, whereas according to the advertisements it should be from four to ten times. On the other hand, the lean beef contains much more protein than the cereals; and furthermore, the body would actually digest a much larger proportion of the protein of the beef than of that of the

cereal. Consequently, as a source of protein the cereal preparations by no means compare with the beef. This, rather than the energy value, is in reality of most significance, because in the cereals the proportion of energy material is too large and that of building material too small for proper nutrition without the use of some material richer in protein.

If the cereal preparations were compared with cheese the latter would appear much superior as a source of both protein and energy.

Other claims, such as that the preparation is very concentrated, and a few spoonsful of it suffice for a whole meal, are likewise so ridiculous that it seems hardly possible that any one can believe them. Four teaspoons of the average cereal product (which is about as concentrated as it is possible to make such materials), would not furnish over a tenth of the protein and energy that a man at moderate work would obtain from his ordinary meal.

It is not the purpose here to take up in detail the absurdities of the various advertisements. One or two typical specimens are considered simply to indicate to what extent any such extravagant statements should be believed. One other feature might also be mentioned, that is advertising the preparations as if they partake of the nature of patent medicines. Many of the statements of this character also pass beyond the realm of fact into that of ludicrous fancy.

For instance, a certain preparation may be recommended because it contains "the nitrates or muscle makers, the carbonates or heat makers, and the phosphates or brain makers;" and it has been very sagely claimed in one advertisement that "if a person should eat only foods containing nitrates, carbonates and phosphates, the larger portion of all aches and pains would disappear." There is a grain of truth in the last statement, but hardly such as the writer of the advertisement intended. If a person should eat food containing any considerable proportion of some nitrates, aches and pains would most certainly disappear, along with the person who ate such food. Nitrates are not muscle makers, but mineral salts, some of which are actually poisonous to the human organism. Nitrate of soda, so largely used in growing crops, is a familiar example. Fortunately the cereal preparations do not contain nitrates.

Carbonates are also mineral salts, and although they may be present in very small quantities in food, it is not these but the carbohydrates and fats that are the heat producers. A familiar example of the carbonates is the bicarbonate of soda used in baking.

It is needless to continue such discussion. Enough has been stated to show that little account should be taken of the exaggerated statements concerning the nutrive value of cereal preparations. The most that can be said for these products is that in actual composition they very much resemble other food products from the same grains. But this is quite sufficient.

DIGESTIBILITY OF CEREAL PREPARATIONS.

The chemical composition of a food material merely shows the kinds and quantities of nutritive ingredients it contains. The actual nutritive value of the material, however, depends upon the extent to which the different nutrients may be digested and absorbed. Most food materials when eaten are in such form that they cannot be taken directly into the circulation, but must first be converted into substances that are capable of being absorbed. This change is brought about in the alimentary canal, by the action of certain ferments in the digestive juices that are there mixed with the food. Any part of a food substance that for any reason is capable of resisting the action of the digestive juices cannot be absorbed, and therefore does not serve to nourish the body.

For this reason one very essential part of the study of the nutritive value of foods consists in determining what quantities of the nutrients of different food materials are digested when eaten. Such information is obtained from actual experiments with men. Several such digestion experiments with cereal breakfast foods made at this station are described in the preceding article in this report. Similar experiments have also been made elsewhere with other cereal preparations. The number of experiments yet completed is hardly large enough for definite conclusions regarding all sorts of cereal products; for instance experiments with corn, rice and barley products are not yet reported; but the information already obtained is decidedly interesting, as will appear from a consideration of the figures summarized in the following table. The figures are here given

in round numbers derived from averages of the results of several experiments. There were variations in the results of the separate experiments, but in no case was the result for a single experiment with a given product very widely different from the average of all experiments for the same product. Furthermore, the differences for the same subject on different brands of similar preparations were no larger than those for different subjects on the same brand. The proportions given are therefore considered fairly representative, though of course they might change slightly with a larger number of experiments included in the average.

TABLE 92.

Digestibility of nutrients and availability of energy in certain kinds of cereal breakfast foods.

KIND OF PREPARATION AND CONDITION WHEN PURCHASED.	PROPORTIONS OF NUTRIENTS ACTUALLY AVAILABLE.		PROPORTIONS OF ENERGY ACTUALLY UTILIZED.
	Protein.	Carbohydrates.	
	Per cent.	Per cent.	Per cent.
Wheat, raw,	83	93	86
Wheat, cooked,	74	92	84
Wheat, cooked and malted,	77	92	85
Wheat and Barley, cooked,	74	93	86
Oats, raw,	77	96	85

For the nutrients the figures represent the proportions of the nutrients of the cereals that were actually digested and made available to the body for the building of tissue and the yielding of energy. The figures for energy represent the proportions of total energy of the cereals that were actually utilized for bodily heat and muscular activity. It will be noticed that no figures are given for digestibility of fat of cereal preparations. The quantities of fat in all but the oat products were too small to be taken into consideration.

The wheat products are given in three groups. The first group includes those that have not been cooked during their preparation, such as rolled or crushed wheat. They must, of course, be cooked before eaten. In the experiments they were

cooked by boiling. The second group includes the wheat products that have been cooked and are ready to eat as purchased, such as shredded or parched wheat. None of the products included in this group had been malted, however. The malted wheat products, which are also cooked and ready to eat when taken from the package, are included in the third group.

The preparation of mixed grains included in the table was claimed to be a mixture of wheat and barley. It was cooked and ready to eat as purchased.

The oat preparations consisted of different brands of rolled oats. They were all cooked in the usual manner before eating.

The differences in the proportions of carbohydrates digested from the different products are very small, and the amount of energy actually available to the body was even more uniform. As regards protein, the proportions digested from the different products were much the same except in the case of the boiled wheat, in which it was noticeably higher. It would appear, then, that at least so far as the subjects of these experiments are concerned the more elaborately prepared products had no advantage over the simpler preparations. Indeed, because of the larger proportion of protein digested, this being, as already explained, the most essential nutrient, whatever advantage there was would rather appear to be with the preparations that were neither malted nor cooked when purchased.

This difference in the digestibility of the uncooked and the cooked and malted wheat products was very likely due largely to the fact that the uncooked preparations were those from which the coarse branny material had been removed, whereas the cooked preparations were those which contained the whole of the wheat kernel including the bran. At least it has been found in similar experiments with different grades of wheat flour that those containing the bran are less digestible than those from which it had been removed in milling. From the results of a large number of experiments with bread from such flours it has been found that they compare in digestibility as follows:

	PROTEIN.	CARBOHYDRATES.
White bread,	88 per cent.	98 per cent.
Entire wheat bread,	82 per cent.	94 per cent.
Graham bread,	76 per cent.	90 per cent.

Comparing these figures with those for wheat preparations it will be seen that as regards digestibility of protein the uncooked preparations will agree with entire wheat bread, and the cooked preparations agree with the graham bread.

Effect of the so-called "predigestion" of cereal products.—The nutrients of the so-called "predigested" or malted products were no more thoroughly digested than those of the preparations not malted. In other words, the treatment with malt did not render available to the body any greater amount of nutrients than was obtained from the preparations not malted. What, then, is the supposed advantage of this process?

It has already been stated that a part of the natural process of digestion consists in the conversion of starch into sugar. If for any reason the digestion of starch is not easily carried on in the body, or is accompanied by discomfort, then it might be some advantage, at least temporarily, to convert the starch into sugar outside of the body. The starch of grain may be converted into sugar by the action of the ferment in malt. The supposed object of the malting process, therefore, is to increase the ease with which the carbohydrates of the cereal may be digested. The success of the treatment depends upon the extent to which the starch has actually been converted.

The actual conversion of starch by such treatment appears to be at best rather limited. Several studies have been made to learn how much of the starch in "predigested" preparations has really been converted into soluble material. In some cases malt sugar has been found in appreciable quantities, but in no case did one-half of the starch appear to have been converted; and in a considerable number of cases only a quarter or less had been changed. The average of all results would hardly equal a third of the total starch present.

On the other hand, some of the investigations have given grounds for suspicion that none of the starch had been converted into sugar, but maltose or dextrine had simply been added to the unmalted grain. It has already been explained that the result of the action of the malt ferment on starch is the production of malt sugar, and not grape sugar, the two being quite different. One investigator has suggested that "a

claim that grape sugar is present is based wholly on a wrong interpretation of the malting process or else is a confession of the addition of commercial glucose to the product.''

It might also be remarked that in the case of a few of the so-called ''predigested'' preparations examined the grains had apparently not been put through the malting process, but before being finally cooked a little malt had probably been added to give the peculiar flavor of malted preparations.

Although the actual predigestion of food might afford some benefit to persons with weak digestive powers, it would offer no advantage to persons with normal digestion, who are fortunately still in the large majority. Digestive organs were intended to be used, and like all other organs are better for exercise. In fact some specialists even claim that one reason for indigestion is that the food is so thoroughly softened, and even partially predigested, by cooking that these organs are not given sufficient work, and hence become sluggish, though this question has not been definitely decided by experiment. There is little doubt, however, that food materials that require no effort on the part of the digestive organs are not especially adapted for persons in health. Fortunately, such foods are not common. The so-called ''predigested'' foods are not always all their advertisements would suggest. Since they differ so little from other preparations, the ordinary individual may take them or not, as he chooses.

COOKING CEREAL FOODS.

In a certain sense some food materials may be said to be partially predigested by cooking. At least a part of the process of digestion consists in converting materials that are not soluble into others that are. The effect of cooking upon starch, which is not soluble, is to convert it into soluble material, and to that extent the cooking may be said to resemble part of the process of digestion. For instance, it has been found that when raw cereals were thoroughly boiled for at least an hour, the proportion of soluble carbohydrates present was decidedly larger than in many of the same cereals that had been malted; and the proportion of soluble carbohydrates in the latter was still further increased by boiling.

It is quite necessary that the raw cereals be cooked, for when uncooked the starch is not readily digested in the intestine. Much of it appears to resist the action of the digestive juices. The object of the cooking, therefore, is not that the starch may be partially predigested, but that it may be rendered capable of being digested at all. Not only that, but cooking also improves the flavor of the cereals, which is also an advantage, because agreeable flavors apparently aid in stimulating the flow of digestive juices, and thus aid in digestion.

Very little accurate inquiry has been made regarding the length of time actually required for the proper cooking of different cereals. The preparations that are entirely uncooked, of course, require longest cooking, and in boiling they should be cooked at least an hour. It is sometimes claimed that the preparations cooked entirely at home are preferable to those partially cooked when purchased; but it is difficult to see why the latter, if further cooked sufficiently before eating, should not be as digestible as the former. The difficulty generally lies in the fact that they are sometimes merely warmed in water. They should always be cooked at least as long as stated in the accompanying directions, and for many of them still longer cooking is better.

ADULTERATION OF PREPARED CEREAL PRODUCTS.

Several of the experiment stations, especially in States having "pure food" laws, have studied the cereal preparations on the market in order to learn whether or not they are adulterated. In general, the materials appear to be prepared from sound, clean grain, and quite free from adulteration, at least so far as injurious substances are concerned. In some of the preparations there have been found ingredients which the manufacturers might not willingly admit to have been added, but these were harmless in character. The worst fraud practised in this class of food materials, for it amounts to positive fraud, is in the claims for quite impossible qualities and nutritive values made in many of the advertisements. They are deliberately planned to deceive, and to prey upon ignorance and credulity. A consideration of this feature, however, is hardly in place in a discussion of adulteration.

THE RELATIVE ECONOMY OF CEREAL PREPARATIONS.

Since the nutritive value of any food material is determined by the amounts of protein and energy it actually supplies, the real cheapness or dearness of the food depends upon the actual cost of the protein and energy it contains. That is, in determining the pecuniary economy of the material it is essential to consider both its price per pound and its chemical composition. The relative economy of different materials may be illustrated in a very simple manner by a comparison of the quantities of protein and energy that will be obtained in them for a given sum. Such a comparison is given for a number of the cereal products and for a few other common foods by the figures in the following table, showing how much total protein and energy each will supply for 10 cents. The figures of the cereal products are based upon the analyses given in Table 90. It would be far preferable to compare quantities of digestible protein and available energy, but the digestibility of several of the cereal products is not yet sufficiently well known.

The prices here given for the various products are those of several different localities. In some cases considerable variation was found in the price of the same brand, as shown in the table. In such cases the average price was used in computing the amounts of protein and energy for 10 cents. The weight per package and the amount of cereal food in the package are also, in the majority of cases, averages of several weighings. In some instances an appreciable difference was found in the weight of the contents of two packages of the same brand. For a number of the brands not enough information was at hand regarding the weight of the cereal contents; and such brands are omitted from the table. This accounts for the fact that the list in this table is smaller than that in Table 90. The number of brands here included, however, is quite sufficient to indicate average variations in relative economy.

The figures in the table are readily understood. For example, the first item, Cream of Wheat, varied in price from 13 to 17 cents per package in different localities. The average price was taken as 15 cents. The average weight of the contents of a package was 1.82 pounds. This would make the actual cost of the food 8.2 cents per pound. The amount of cereal that 10 cents would pay for would furnish, according to

TABLE 93.

Comparative cost of total nutrients and energy of different cereal breakfast foods.

KIND OF PREPARATION.	COST PER PACKAGE.	Actual weight of food in package.†	Price per pound.	AMOUNTS FOR 10 CENTS.	
				Protein.	Energy.
WHEAT PREPARATIONS.	Cents.	Lbs.	Cents.	Lbs.	Cals.
Uncooked and partially cooked:					
Cream of Wheat,	(13 –17) 15	1.82	8.2	0.15	2,220
Hecker's Farina,	12.5*	.93	13.4	.08	1,325
Pettijohn's Breakfast Food,	12.5	1.85	6.8	.16	2,678
Pillsbury's Vitos,	(12½–15) 13.8	2.05	6.7	.19	2,723
Ralston's Health Breakfast Food,	13	1.81	7.2	.18	2,529
Rolled Wheat—Old Grist Mill,	(12½–15) 13.8	2.01	6.9	.16	2,642
Wheat Flakes—Fruen's,	13	1.84	7.1	.14	2,555
Granose,	15	.75	20.0	.07	902
Crescent,	15	.90	16.7	.06	1,063
Wheatena,	25	2.27	11.0	.13	1,728
Wheatlet,	(12½–15) 13.8	1.90	7.3	.17	2,502
Wheatine,	15	1.89	7.9	.13	2,268
Cooked:					
Parched Farinose,	(12–15) 13.5	2.03	6.7	.21	2,856
Shredded Whole Wheat Biscuit,	12.5	.88	14.2	.08	1,286
OAT PREPARATIONS.					
Rolled Oats—Buckeye,	10	1.92	5.2	.29	3,837
Hecker's,	(10–12½) 11.3	1.88	6.0	.29	3,355
Hornby's,	15	2.00	7.5	.21	2,657
Quaker,	12.5	1.89	6.6	.25	3,048
Ralston's,	10	1.73	5.8	.29	3,486
Saxon,	25	4.41	5.7	.31	3,472
Rolled Oats in bulk,	—	—	4.0	.40	5,037
CORN PREPARATIONS.					
Uncooked and partially cooked:					
Cerealine Flakes,	15	1.64	9.1	.10	1,932
Hominy—Hecker's,	(12 –15) 13.5	2.97	4.5	.19	3,894
H. O. Co.'s,	(12½–15) 13.8	2.95	4.7	.18	3,772
Nichol's,	22	4.92	4.5	.19	4,018
Samp—Nichol's Snow White,	10	4.66	2.1	.39	8,253

* In almost every instance where the cost is stated to be 12½ cents, the price is 13 cents per package, two for 25 cents.

† In some instances the weight of the package itself was estimated. The error can be but small.

TABLE 93.—*(Continued.)*

KIND OF PREPARATION.	COST PER PACKAGE.	Actual weight of food in package.†	Price per pound.	AMOUNTS FOR 10 CENTS. Protein.	Energy.
CORN PREPARATIONS.—*(Con.)*	Cents.	Lbs.	Cents.	Lbs.	Cals.
Cooked:					
Korn Krisp,	(10 –15) 12.5*	1.04	12.0	0.09	1,557
Toasted Corn Flakes,	15	1.04	14.4	.06	1,227
Corn meal, granular (bulk),	—	—	2.5	.37	7,041
RICE PREPARATIONS.					
Cook's Flaked Rice,	(13 –15) 14	.81	17.3	.05	1,026
Polished rice (bulk),	—	—	9.0	.08	1,911
BARLEY PREPARATIONS.					
Ralston's Barley Food,	13	1.89	6.9	.15	2,642
MIXED GRAIN PREPARATIONS.					
Grape-Nuts,	15	1.03	14.6	.08	1,288
MALTED PREPARATIONS.					
From Wheat—Brittle Bits,	13	1.05	12.4	.11	1,503
Force,	15	.90	16.7	.07	1,083
Malt Break. Food,	(12½–15) 13.8	1.44	9.6	.14	1,956
Malta Vita,	15	1.14	13.2	.09	1,358
From Oats—Malt Oats Br. Food,	12.5	1.36	9.2	.18	2,171
Norka Malted Oats,	15	1.14	13.2	.12	1,444
Beefsteak, round,	—	—	15.0	.13	693
Milk,	—	—	3.0	.11	1,136
Wheat Flour—Graham,	—	—	4.0	.33	4,511
Entire Wheat,	—	—	5.0	.27	3,623
White,	—	—	3.5	.33	5,069
Wheat bread, white,	—	—	5.0	.18	2,619
Crackers,	—	—	8.0	.13	2,530
Macaroni,	—	—	10.0	.13	1,804
Sugar,	—	—	6.0	—	2,989
Beans, pea, dried,	—	—	4.0	.56	4,487
Peas, dried,	—	—	4.0	.62	4,652
Potatoes, white,	—	—	12.5	.01	2,604
Oranges,	—	—	7.0	.01	247

*In almost every instance where the cost is stated to be 12½ cents, the price is 13 cents per package, two for 25 cents.

† In some instances the weight of the package itself was estimated. The error can be but small.

the average composition for this material given in Table 90 preceding, 0.15 pound of protein and 2220 calories of energy. Comparing the latter figures for the different preparations affords an indication of their relative economy. For instance, among the wheat preparations here included the extreme difference is that between Parched Farinose, furnishing 0.21 pound of protein and 2856 calories of energy, and Granose flakes supplying 0.07 pound of protein and 902 calories of energy, for the same sum.

The largest amounts of protein and energy for 10 cents were found in samp and rolled oats in bulk. The amount of protein was practically the same in both, but much more energy was obtained in the samp. Next to the oats in bulk as regards actual cheapness of protein and energy are the various package oat preparations; then follow, in the order named, the hominy, the majority of the wheat preparations, the barley preparation, some of the malted foods, and the prepared rice.

In comparing the different preparations as regards economy, one other matter must be taken into consideration, namely that of cooking. For instance, Pillsbury's Vito's and Parched Farinose supplied very nearly the same quantity of protein and energy for the same sum, but the latter was ready to eat, whereas the former had to be cooked. Under some circumstances the cooked material might be decidedly the more economical. In the large majority of cases the difference between the cooked and the uncooked preparations is very much larger than this. In many cases the increase in the price of the cooked preparations seems to be somewhat excessive, even when the extra cost of preparing is taken into consideration. Whether or not the saving of heat and labor compensates for the extra cost must be decided according to individual circumstances. If there is a fire in the kitchen range for other purposes there would be no extra cost of fuel, and probably little extra labor in cooking; but if the fire had to be kept going simply to cook the cereal, or if a gas range were used for the cooking, the cost of fuel would have to be taken into account; and if time and labor were valuable the convenience of the ready-to-eat cereal might counterbalance the extra cost. The ready-to-eat preparations are at any rate preferable to the others insufficiently cooked.

In comparing the breakfast foods with some of the other food materials included in the table, the uncooked preparations may be compared with such articles as the wheat flours, macaroni, dried beans and peas, and the cooked preparations with bread and crackers. It will be seen that the amounts of protein and energy for 10 cents are about as large in the bread and crackers as in the moderate priced cooked cereal preparations, and larger than in the higher priced ones. The wheat flours for the same sum furnish almost twice as much protein and energy as the uncooked wheat preparations, and considerably more than even the oat preparations, being surpassed only by rolled oats in bulk and samp. The beans and peas supply almost as much energy and much more protein than the oats in bulk.

SUMMARY.

The difference between the various cereal preparations is principally one of process of manufacture. Some contain the whole of the grain, whereas with others the bran and germ have been removed in their preparation. Some are entirely uncooked, some are partially cooked, and some are wholly cooked and ready to eat as purchased. Among the latter are the so-called "predigested" or "malted" preparations.

The composition of the different products depends upon that of the grain from which they are made, and the extent to which the bran and germ have been removed in the manufacture. In general the prepared product from any grain has much the same composition as that of flour or meal from the same grain. Different brands of similar nature when made from the same grain do not differ in average composition any more widely than different lots of the same brand.

Different prepared products from the same grain show no marked differences in respect to the amounts of nutrients that may be actually digested. The differences in actual nutritive value of the products from the same grain are therefore on the average so small that they may be disregarded in choosing between them. However, the oat preparations contain noticeably larger proportions of nutrients and energy than those of other grains, and as they are when properly cooked no less thoroughly digested, the actual nutritive value of the oat preparations appears to be greater than that of the preparations from other grains.

The nutritive value of the "malted" or so-called "predigested" preparations is no greater than that of other preparations from the same grains. In some instances the attempts to convert insoluble starch into more soluble material by the use of malt have been to a small degree successful, and to that extent the preparations have been rendered more easily digestible; but just as much and even more is accomplished by thorough cooking. In most of the malted preparations the quantity of starch actually converted is, however, very small, and in some cases none has been changed.

The thoroughness of cooking has quite as much influence upon the actual food value of the preparations as the small differences in composition. If the cereals are not thoroughly cooked some of the nutritive material will escape the action of the digestive juices. The partially cooked cereals should always be further cooked for at least as long a time as directed, and even longer cooking will be advantageous in many cases.

There are very wide differences in the cost of similar preparations. This depends upon not only the cost per package, but also, and more especially, upon the actual weight of material in the package. In many cases the market price has little connection with the nutritive value or even the cost of materials and preparation. The uncooked cereals, especially those bought in bulk, are the least expensive per pound, but the cost of fuel for cooking them may be sufficient to render their use no more economical than that of the lower priced cooked cereals. The convenience of the latter may therefore sometimes compensate for their higher cost. These considerations of course vary with circumstances, and each one must decide them for himself.

In conclusion, then, it may be stated that in general the prepared cereal products are all wholesome and nutritious, and when reasonable in price are economical sources of nutrients and energy, especially when compared with meats or green vegetables. The different preparations from the same grain resemble each other quite closely in actual nutritive value. A curious name or appearance or process of preparation does not indicate any extraordinary food value, and the intelligent buyer may make his choice largely in accordance with taste, distrusting the extravagant claims made for any particular brand. If he considers economy, however, he is hardly justified in paying for some brands prices which are equivalent to 15 to 20 cents a pound when other preparations of equal value may be had for 6 or 8 cents a pound.

METEOROLOGICAL OBSERVATIONS AT STORRS AND GENERAL WEATHER AND CROP REVIEW.

REPORTED BY W. A. STOCKING, JR.

The Station has continued its meteorological observations during the year, as in past years. The equipment at the Station remains practically the same, and consists of the ordinary instruments for recording temperatures, atmospheric pressure, atmospheric moisture, rainfall, and snowfall. These instruments are similar to those used by the Weather Bureau of the United States Department of Agriculture. Observations are made three times each day—at 7 A. M., 2 P. M., and 9 P. M. The summaries given in the following tables are made up from the results of these daily observations. In Table 94 is given a summary of the observations made at Storrs during the year 1903.

The amount and distribution of precipitation during the growing season is one of the most important factors in crop production, and in order to get more general information upon the rainfall in various parts of the State, this Station has for several years coöperated with men in different parts of the State. The Station furnishes the necessary apparatus, and these men in return send to the Station each month the record of the rainfall for their sections. These records, together with a number furnished by the New England section of the Weather Bureau, are given in Table 95.

The total precipitation for the year as recorded at Storrs was 48.45 inches. This was about 3.5 inches less than for 1902, but about an inch above the average for the past fifteen years. The total rainfall during the growing months, May to October inclusive, was 23.42 inches. The rain was quite evenly distributed throughout the year, with the exception of the spring and early summer. The total for April was 2.81 inches, which

is somewhat below the average. In May there was but .50 of an inch recorded at Storrs, and a similar condition existed throughout a greater part of the State. This is 3.5 inches less than the average for this month for the past fifteen years. June, however, made up this deficiency with 9.24 inches. This is 6.73 inches in excess of the average for June as shown by the records of the past fifteen years. During the remaining months the rainfall was not far from normal.

The mean temperature for the year was 46.8°, which is only .2 below the average for the past fifteen years. March, April, and May, however, were much warmer than usual, especially March, which had a mean of 6.7 higher than the average. June, however, was 5.7° colder than the average for the past fifteen years. August was 5.5 above, and the other months did not vary greatly from the fifteen year averages.

The spring season opened far in advance of the usual time. Snow and frost disappeared early in March, and in many parts of the State much plowing was done during this month. There was an abundance of precipitation and an unusually high temperature, so that the season opened from two to three weeks in advance of the average. During April the advance was not so rapid, and the rainfall was small. By the early part of May the conditions for crop production became serious because of the exceptionally small rainfall, there being less than one inch in most parts of the State, and in some parts barely a quarter of an inch fell during the entire month. The ground became so dry that seed failed to germinate, and pastures began to dry up. Strawberries ripened prematurely as a result of the dry weather, and were on the market two to three weeks in advance of the usual time. The drought continued until the second week in June, and was followed by unusual rains amounting to 9.25 inches before the first of July. Many dry meadows and much early hay had been practically ruined before the rain came, but the later grasses picked up with unusual rapidity, so that grass which was not cut until July gave a much better yield than was supposed to be possible before the rains began. On account of the unfavorable weather during July and August, corn and other crops were very backward. September and October were favorable for late growth, but corn was unable to make up for the unfavorable conditions

earlier in the season, and a large proportion was cut before it was mature in order to escape frost. Potatoes were badly affected by late blight. Tobacco was unusually good. The leaves, though somewhat smaller than those of some years, were of fine texture and remarkably free from blemishes due to insects. The second cutting of hay was heavy in many sections. Fall pasturage was abundant, and the soil was in good condition for fall seeding.

The date of the last killing frost in the spring varied from March 26 at Canton to May 26 at Torrington. In most parts of the State there was no frost after May 2 or 3, and in many parts not after the first week in April. Frost held off considerably later than usual in the fall, having caused no damage in the State until September 29, and in many sections even the most delicate plants were not injured until the third week in October. At Storrs the last killing frost in the spring was on May 3, and the first in the fall was on October 15, leaving a growing season free from frost of 165 days, which is nineteen days longer than the average for the past fifteen years.

TABLE 94.

Meteorological observations for 1903.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Highest barometer, - -	30.70	30.55	30.70	30.55	30.58	30.47	30.25	30.48	30.48	30.43	30.79	30.65	—
Lowest barometer, - -	29.28	29.20	29.55	29.53	29.81	29.59	29.66	29.73	29.77	29.53	29.49	29.26	—
Mean barometer, - -	29.99	30.07	30.25	29.95	30.20	30.02	29.97	30.07	30.19	30.07	30.06	30.27	—
Highest temperature, -	47	57	70	81	89	82	90	82	86	73	69	51	—
Lowest temperature, -	-4	-4	16	22	28	40	45	43	35	25	7	-4	—
Mean temperature, - -	26	28	43	46	58	58	68	62	61	51	35	25	—
Relative humidity, - -	—	—	—	64	62	83	73	80	77	74	—	—	—
Total precipitation, inches,	3.73	5.18	7.09	2.81	.50	9.24	4.56	4.52	1.81	2.79	1.95	4.27	48.45
No. days with .01 inch or more precipitation,	10	10	9	7	4	12	11	9	7	11	4	9	103
No. days clear, - -	5	12	8	11	17	5	12	7	14	11	14	13	129
No. days partly cloudy, -	13	6	11	12	10	4	12	11	9	8	9	11	116
No. days cloudy, - -	13	10	12	7	4	21	7	13	7	12	7	7	120

Table 95.

Rainfall during six months ending October 31, 1903.

Locality.	Observer.	Inches per Month.						Total.
		May.	June.	July.	August.	September.	October.	
Canton, - -	G. J. Case, - -	0.81	11.69	3.86	7.34	4.46	4.10	32.26
Clark's Falls, -	E. D. Chapman, -	0.55	6.40	4.68	5.00	1.01	3.02	20.66
Colchester, - -	S. P. Willard, -	0.42	8.40	3.72	6.00	2.97	4.12	25.63
Cream Hill, - -	C. L. Gold, -	1.39	9.74	4.07	5.65	2.85	6.39	30.09
Falls Village, -	M. H. Dean, -	0.97	10.01	2.64	5.93	2.02	6.04	27.61
Grove Beach, -	C. M. Templeman,	0.38	6.41	2.03	5.73	2.46	3.44	20.45
Hartford, - -	W. E. Boardman,	0.88	10.55	5.73	7.79	3.22	2.94	31.11
Hawleyville, -	E. N. Hawley, -	1.61	10.38	2.56	7.41	6.17	6.32	34.45
New Haven, -	Weather Bureau,	0.31	7.41	2.17	6.96	2.20	2.94	21.99
New London, -	J. R. May, - -	0.54	4.44	2.00	5.70	1.31	2.14	16.13
N. Grosvenor Dale,	Grosvenor D. Co.,	0.49	7.33	3.51	4.59	1.70	3.11	20.73
Norwalk, - -	G. C. Comstock, -	0.07	10.54	3.03	10.05	2.61	5.07	31.37
Southington, -	L. Andrews, -	0.50	12.10	3.65	6.90	3.00	3.00	29.15
Storrs, - - -	Agr. Expt. Stat'n,	0.50	9.24	4.56	4.52	1.81	2.79	23.42
Torrington, - -	Prof. E. H. Forbes	0.82	10.19	4.80	5.66	2.95	4.50	28.92
Voluntown, - -	Rev. E. Dewhurst,	0.46	6.88	2.94	3.79	1.13	3.70	18.90
Waterbury, - -	N. J. Wilton, -	0.73	11.25	3.71	6.36	3.02	4.77	29.84
W. Simsbury, -	S. T. Stockwell, -	0.73	9.79	3.79	7.21	4.57	3.70	29.79
Lebanon, - -	E. A. Hoxie, -	0.24	6.69	3.56	4.87	3.60	4.83	23.79
Madison, - -	J. D. Kelsey, -	0.32	7.12	1.86	5.10	1.60	3.97	19.97
So. Manchester, -	K. B. Loomis, -	0.95	9.05	4.41	5.62	1.97	3.18	25.18
Norfolk, - -	G. O. Stanard, -	0.75	10.14	—	—	—	—	—
Average, - -	—	0.66	8.90	3.49	6.10	2.70	4.00	25.78

TABLE 96.—*Monthly mean temperature for past 15 years.*

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Mean.
1888, - -	—	—	—	—	—	65.3	66.4	67.3	57.1	43.8	39.7	30.0	—
1889, - -	30.8	22.1	34.9	45.6	58.4	65.2	67.9	64.8	59.7	45.8	40.9	35.1	47.6
1890, - -	32.0	31.7	30.8	44.7	54.9	63.3	67.5	66.0	59.5	47.6	37.9	23.4	46.6
1891, - -	28.8	29.3	31.9	46.1	54.1	63.9	65.2	68.4	63.7	48.3	38.2	37.0	47.9
1892, - -	25.5	26.9	29.9	44.9	53.6	67.0	69.2	67.4	59.1	48.5	37.6	25.5	46.3
1893, - -	17.3	23.5	30.3	42.0	54.5	64.2	67.9	68.0	55.9	51.7	38.1	27.8	45.1
1894, - -	27.7	23.0	38.6	44.7	56.4	66.0	70.9	65.8	63.0	50.6	34.1	28.2	47.4
1895, - -	24.4	19.9	31.1	44.1	57.3	66.7	66.1	68.3	63.1	45.0	41.7	32.6	46.7
1896, - -	21.8	26.3	28.5	47.5	59.9	63.2	69.6	68.5	59.9	47.2	43.5	26.8	46.9
1897, - -	25.0	27.0	34.0	46.0	56.0	62.0	69.0	66.0	60.0	51.0	39.0	31.0	47.2
1898, - -	25.0	28.0	40.0	42.0	54.0	64.0	70.0	69.0	63.0	52.0	38.0	29.0	47.8
1899, - -	25.0	22.0	31.0	45.0	56.0	67.0	68.0	67.0	59.0	52.0	39.0	31.0	46.8
1900, - -	27.0	26.0	30.0	46.0	55.0	66.0	71.0	69.0	64.0	54.0	41.0	29.0	48.2
1901, - -	25.0	19.0	33.0	45.0	54.0	67.0	71.0	66.0	62.0	50.0	33.0	29.0	46.2
1902, - -	24.0	25.0	41.0	46.0	55.0	64.0	66.0	66.0	59.0	48.0	44.0	23.0	46.8
Average, -	25.7	25.0	36.4	45.0	55.7	65.0	68.4	67.2	60.5	49.0	39.0	29.2	47.0

TABLE 97.—*Monthly precipitation for the past 15 years.*

YEAR.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1888, - -	—	—	—	—	—	2.10	1.93	4.97	8.45	6.35	4.94	5.28	—
1889, - -	4.03	1.64	1.96	3.49	2.16	3.50	11.39	3.78	4.00	5.52	5.91	2.88	50.26
1890, - -	2.66	3.28	6.12	3.15	6.33	2.79	2.81	4.26	7.19	5.25	0.82	4.21	48.87
1891, - -	8.52	5.64	4.42	3.51	2.50	1.84	4.96	3.95	4.08	4.14	3.09	4.96	51.61
1892, - -	4.91	1.60	3.00	0.70	5.60	2.77	3.25	5.20	1.40	1.09	5.41	1.35	36.28
1893, - -	2.39	5.88	4.67	3.82	7.12	1.98	1.58	3.79	2.58	6.71	2.45	3.68	46.65
1894, - -	2.24	3.13	1.18	2.67	3.58	0.59	2.09	2.37	3.01	4.16	4.00	4.31	33.33
1895, - -	5.78	0.63	2.62	4.27	2.16	1.78	4.13	3.48	2.97	6.74	6.97	4.12	45.65
1896, - -	1.60	7.10	4.86	0.80	2.72	1.78	3.22	2.17	7.03	3.60	2.49	2.67	40.58
1897, - -	3.84	3.40	3.66	2.37	4.44	2.79	12.24	5.23	1.39	0.92	7.14	5.61	53.03
1898, - -	4.70	4.03	3.09	4.44	3.81	2.48	6.24	5.87	2.22	6.18	6.11	1.96	51.13
1899, - -	3.76	3.97	5.58	2.20	1.17	3.72	5.55	3.27	3.31	1.54	2.10	2.14	38.31
1900, - -	3.42	7.31	6.43	2.67	4.91	4.31	2.76	2.03	2.27	3.21	6.79	2.22	48.64
1901, - -	8.50	1.05	7.18	9.51	6.30	1.96	5.54	7.58	4.33	1.97	3.04	9.55	66.51
1902, - -	2.53	5.11	6.35	3.81	1.73	3.25	7.48	2.17	7.05	5.68	1.10	5.86	52.12
Average, -	4.21	3.84	4.37	3.39	4.00	2.51	5.01	4.04	4.08	4.20	4.16	4.05	47.36

TABLE 98.

Growing season for past 15 years.

YEAR.	LAST KILLING FROST, SPRING.	FIRST KILLING FROST, FALL.	GROWING SEASON.
1888, - - -	May 16	September 7	114 days
1889, - - -	May 4	September 23	142 days
1890, - - -	April 29	September 25	148 days
1891, - - -	May 5	October 17	164 days
1892, - - -	April 30	September 21	144 days
1893, - - -	May 8	October 17	161 days
1894, - - -	May 15	September 26	134 days
1895, - - -	May 17	October 15	150 days
1896, - - -	May 2	September 24	144 days
1897, - - -	April 22	September 28	159 days
1898, - - -	May 10	October 17	160 days
1899, - - -	May 4	September 15	134 days
1900, - - -	May 11	October 18	158 days
1901, - - -	May 6	September 26	142 days
1902, - - -	May 28	October 10	135 days
Average, - -	—	—	146 days

INDEX.